

# Ajeenkya DY Patil School of Engineering, Lohegaon, Pune, Maharashtra, India

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(Approved by AICTE, New Delhi, Govt. of Maharashtra & affiliated to Savitribai Phule Pune University)

International Conference on Innovation & Advancements in Civil Engineering

# (ICIAC-2025)

# 15<sup>th</sup> May 2025

# In Association With:



ISBN: 978-81-984557-3-4

# About the College

Ajeenkya D Y Patil School of Engineering (ADYPSOE) is one of the most prestigious academic groups in the Pune City and state of Maharashtra which is Approved by AICTE and Affiliated to S.P. Pune University.

ADYPSOE was established in 2010 by the Chairman of Ajeenkya D. Y. Patil Group with excellent infrastructure spread over green campus with spacious buildings.

The college has developed excellent infra-structural facilities with well-equipped laboratories and an enriched library, which are updated regularly. The facilities and in- depth teaching is improvising students to understand the recent trends of Engineering and Technology. The College provides not only technical education to students but also conducts many co-curricular and extra-curricular programs, which ensure multifaceted development of students.

# Aim & Objective of the Conference- ICIAC-2025

The conference is aimed to bring together innovative academics and industrial experts in the field of Engineering and Technology to a common forum. The conference aspires to exhibit the technical excellence of budding technocrats, research scholars, representatives from the academia industry.

The conference is also a space for creating collaborative links between academics and professional practitioners and their workplaces, aiming at long-term sharing of knowledge and discussions of highly current issues.

# **MESSAGE FROM PRESIDENT**



It gives me immense pleasure that the Ajeenkya DY Patil School of Engineering has organized International Conference on Innovation & Advancements in Civil Engineering (ICIAC-2025), in association with International Journal of Innovative Research in Science, Engineering and Technology (IJIRSET). Ever since the inception of our institute, we have been striving for excellence in various departments of Engineering and at the very same time marching forward with the mission of professional as well as technical development.

I believe in promoting events to be organized in Ajeenkya DY Patil School of Engineering which opens research and innovation avenues for students. This International Conference on Innovation & Advancements in Civil Engineering (ICIAC-2025) is one such step towards motivating students and researchers. The conference greatly encourages graduate and Postgraduate students, research scholars and faculty to present innovative ideas and latest discoveries in the field of engineering and Technology. I would like to extend my gratitude towards Research and development cell and all staff who had done excellent job for the success of this conference. I take this opportunity to extend my best wishes to all the participants of this conference for their future endeavors and also aspire that more and more people opt for research and bring laurels to themselves and to the field of education.

Dr. Ajeenkya D.Y. Patil President,ADYPSOE

# **MESSAGE FROM TRUSTEE & ADVISOR**



At the outset, I extend my appreciation and congratulations to Ajeenkya DY Patil School of Engineering for successfully organizing International Conference on Innovation & Advancements in Civil Engineering (ICIAC-2025) on 15th May 2025. Education in general and technical education in particular, must be relevant to rapidly changing needs of the society, industry and business houses. The educational environment must be dynamic and quickly adaptable, so that professionals are capable of shouldering all-encompassing global responsibilities.

I express my sincere thanks to all well-wishers for their valuable guidance and unstinted support, who have been directly or indirectly involved in organizing this conference. May you all always be in pursuit of Excellence.

Dr. Sushant V. Patil,

**Trustee & Advisor, ADYPSOE** 

# **MESSAGE FROM EXECUTIVE VICE PRESIDENT**



It gives me great pleasure to be part of the International Conference on Innovation & Advancements in Civil Engineering (ICIAC-2025) in Ajeenkya D Y Patil School of Engineering campus. The conference proceedings are a collection of research-based articles and papers presented by graduate and post graduate students and research scholars from all over India. These articles not only handle various issues in the field of Technology but also touch an array of topics right from Civil, Mechanical, Electronics branches. Conducting a conference of this magnitude is always encouraging and I would appreciate the efforts of the Ajeenkya D Y Patil School of Engineering in this endeavor.

I hope that the conference will provide a platform for various personnel to introduce innovative ideas and thoughts and exhibit their research skills in the area of all Technologies for sustainable development.

Dr. Kamaljeet Kaur Executive Vice President, ADYPSOE

# **MESSAGE FROM PRINCIPAL**



Education is an instrument to enhance the capabilities of human beings to become knowledgeable, creative and good citizens which resulted in my urge to develop excellent educational facility. I am extremely happy as principal of Ajeenkya D Y Patil School of Engineering, hosting International Conference on Innovation & Advancements in Civil Engineering (ICIAC-2025).

It is a justified gesture to provide a platform for graduate students and researchers to present their work and seek experts' evaluation that provides insight in the work undertaken. I hope that the presentations, discussions, appreciations and suggestions will help in improving their research work. I extend my heartfelt wishes to all the participants who have contributed to making this conference a great success. It gives me pleasure to write for the proceeding of International Conference on Innovation & Advancements in Civil Engineering (ICIAC-2025) an important event. Conferences of this magnitude help the graduate students and researchers to interact amongst themselves as well as experts in various areas. I feel that, with presentations and interactions with experts; students are exposed to the emerging trends in respective domains and the research work being carried out.

I would like to congratulate participants for contributing to this conference. I appreciate conference conveners, faculty coordinators, staff members of Ajeenkya D Y Patil School of Engineering for organizing the National Conference on International Conference on Innovation & Advancements in Civil Engineering (ICIAC-2025).

Dr. Farook Sayyad Principal, ADYPSOE

### **MESSAGE FROM HOD**



It gives me immense pleasure to extend a warm welcome to all participants, delegates, and esteemed guests attending the International Conference on Innovation & Advancements in Civil Engineering (ICIAC-2025). This conference serves as a dynamic platform for researchers, academicians, industry professionals, and students from across the globe to exchange knowledge, present their latest findings, and explore emerging trends in civil engineering.

In today's rapidly evolving world, the field of civil engineering is undergoing a remarkable transformation through innovations in materials, sustainability, digital technologies, and smart infrastructure. ICIAC-2025 reflects our commitment to fostering a culture of innovation and collaborative research that addresses the current and future challenges of the built environment.

The Department of Civil Engineering takes pride in organizing this prestigious event, I am confident that the deliberations and outcomes of ICIAC-2025 will contribute significantly to academic growth, professional networking, and global cooperation.

I wish all participants a fruitful and enriching experience and look forward to the impactful contributions that will emerge from this gathering.

Dr. Pallavi Kharat Head of Department Civil Engineering, ADYPSOE

# **CONVENER'S MESSAGE**



It gives me immense pleasure to welcome you all to the International Conference on Innovation & Advancements in Civil Engineering (ICIAC-2025), organized by the Ajeenkya D Y Patil School of Engineering on the 15th of May, 2025.

The field of Civil Engineering is undergoing rapid transformation, driven by technological innovations, sustainable development goals, and evolving infrastructural demands. ICIAC-2025 serves as a vibrant platform for academicians, researchers, industry professionals, and students to come together and exchange ideas, share research outcomes, and explore collaborative opportunities in addressing the emerging challenges and opportunities in this dynamic domain.

This year's conference focuses on a diverse range of themes including smart infrastructure, green construction technologies, advanced materials, disaster resilience, and digital tools in construction. We are honored to host distinguished keynote speakers and technical experts from across the globe, whose insights will undoubtedly enrich the knowledge base of all participants.

I extend my heartfelt thanks to our esteemed guests, keynote speakers, reviewers, session chairs, organizing committee members, and participants for their unwavering support and enthusiasm. Your presence and contributions are what make this academic gathering a success.

Wishing you all a fruitful and inspiring conference experience at ICIAC-2025.

Prof. Vishwajeet A. Kadlag Convener, ICIAC-2025 Ajeenkya D Y Patil School of Engineering

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# Prediction of Cracks and Recognizing Its Patterns in Geopolymer Concrete Beams using Machine Learning

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**ABSTRACT**: Geopolymer concrete, known for its sustainable properties and high strength, has emerged as a viable alternative to traditional Portland cement concrete. However, the prediction of cracks and the recognition of their patterns in geopolymer concrete beams remain critical challenges that impact structural integrity and durability. This review paper explores various machine learning techniques employed in the analysis of crack formation and pattern recognition in geopolymer concrete. We systematically evaluate the effectiveness of different algorithms, including supervised and unsupervised learning methods, and their applications in crack detection and classification. Additionally, we highlight the integration of image processing techniques and sensor data in enhancing predictive accuracy. The findings indicate that machine learning models significantly improve the understanding of crack behavior in geopolymer concrete, facilitating proactive maintenance strategies. This paper concludes with recommendations for future research directions, emphasizing the need for more comprehensive datasets and the exploration of hybrid machine learning models to advance the field.

**KEYWORDS**: Geopolymer concrete, crack prediction, pattern recognition, machine learning, structural integrity, image processing, predictive maintenance, supervised learning, unsupervised learning, sensor data, hybrid models.

#### I. INTRODUCTION

Geopolymer concrete (GPC) is an innovative building material that utilizes industrial by-products, such as fly ash and slag, to replace traditional Portland cement. Due to its eco-friendly nature and superior mechanical properties, GPC has gained significant attention in the construction industry. Despite its advantages, the assessment of structural performance, particularly in relation to crack formation, remains a critical challenge. Cracks can significantly compromise the load-bearing capacity and longevity of concrete structures, making early detection and accurate prediction essential for maintenance and safety.

Traditional methods for crack detection often rely on visual inspections or manual measurements, which can be subjective and prone to human error. Recent advancements in machine learning (ML) present new opportunities for automating crack detection and improving predictive capabilities. Machine learning algorithms can analyze complex datasets and recognize patterns that may not be readily apparent through conventional methods. By leveraging various data sources, including images captured through high-resolution cameras and sensor readings, ML models can enhance our understanding of crack behaviors in geopolymer concrete beams.

This review aims to provide a comprehensive overview of the state-of-the-art machine learning techniques employed in the prediction of cracks and recognition of their patterns in geopolymer concrete. We will explore different approaches, assess their effectiveness, and discuss the integration of image processing techniques and sensor data. The ultimate goal is to highlight the potential of machine learning in advancing the field of civil engineering and ensuring the structural integrity of geopolymer concrete applications.



Proceedings of International Conference on Innovation & Advancements in Civil Engineering (ICIAC-2025) 15<sup>h</sup> May 2025, Department of Civil Engineering, Ajeenkya D Y Patil School of Engineering, Lohegaon, Pune, India, ISBN: 978-81-984557-3-4



#### Figure1.1: Graphical

#### II. RELATED WORK

# Nashat S. Alghrairi et al., Open Engineering ,2024. "Machine learning-based compressive strength estimation in nanomaterial-modified lightweight concrete"

Nanotechnology has led to the development of unique materials, including nanoparticles in lightweight concrete (LWC) to improve its mechanical, microstructure, freshness, and durability qualities. Accurate models for estimating compressive strength (CS) are crucial for saving time, energy, and money, as well as planning construction schedules. A study involving 2,568 samples used nine models to predict CS of LWC mixtures with or without nanomaterials. The GBT model outperformed other models in predicting CS, with the highest R2 value (0.9) and the lowest RMSE (5.286). The water content was found to be the most important factor influencing CS prediction.

# Qiang Li et al., Scintific Reports, 2023. "Splitting tensile strength prediction of Metakaolin concrete using machine learning techniques"

This paper presents a study on predicting splitting tensile strength (STS) in concrete containing Metakaolin using four machine learning models: Artificial Neural Network (ANN), Support Vector Regression (SVR), Random Forest (RF), and Gradient Boosting Decision Tree (GBDT). The results show GBDT model outperforms other models, demonstrating its potential as a cost-effective and time-efficient prediction tool for STS in concrete.

# Mohammed Alarfaj et al., Elsevier ,2024. "Machine learning based prediction models for spilt tensile strength of fiber reinforced recycled aggregate concrete"

The demand for concrete production has led to a significant annual requirement for raw materials, resulting in a substantial amount of waste concrete. Recycled aggregate concrete has emerged as a promising solution, but faces challenges due to the vulnerability of the hardened mortar attached to natural aggregates. This study focuses on predicting the split tensile strength of fiber reinforced recycled aggregate concrete using five prediction models, including deep neural network models (DNN1 and DNN2), optimizable Gaussian process regression (OGPR), and genetic programming-based GEP1 and GEP2 models. The models exhibited high accuracy in predicting split tensile strength with robust R2 and MAE values. The most significant positive factors were cement, natural coarse aggregates, density of recycle aggregates, and superplasticizer.

#### Mohammed Awad Abuhussain et al., Elsevier ,2024. "Data-driven approaches for strength prediction of alkaliactivated composites"

This study uses data-driven predictive modelling to predict the compressive strength (CS) of Alkali-activated composites (AACs), a promising alternative to Portland cement production and decarbonisation of concrete construction. Four different modelling techniques were used: decision tree, multi-layer perceptron, bagging regressor, and AdaBoost regressor. The AR model outperforms the others, providing a higher coefficient of determination and lower MAPE value. A graphical user interface is also developed for strength prediction.



#### Preetham.S et al., Elixir,2015. "Support Vector Machines Technique in Analysis of Concrete- Critical Review"

This paper presents the state of knowledge on support vector mechanics method (SVM) problems in civil engineering, focusing on concrete. Concrete is widely used in construction, with its use exceeding that of steel, wood, plastics, and aluminum combined. The ready-mix concrete industry is projected to exceed \$100 billion in revenue by 2015, with the US alone producing \$30 billion per year. The paper discusses the role of concrete in shaping modern infrastructure and presents the state of knowledge on SVM for modeling and analytical studies on beams and concrete cubes.

# Rongchuan Cao et al., MDPI, 2022. "Application of Machine Learning Approaches to Predict the Strength Property of Geopolymer Concrete"

The study investigates the use of machine learning (ML) approaches to predict the compressive strength (C-S) of Geopolymer Concrete (GPC) based on fly ash (FA). Various ML techniques were used, including support vector machine (SVM), multilayer perceptron (MLP), and XGBoost (XGB). The results showed that XGB was more accurate, with an R2 value of 0.98, and the XGB model had lesser errors, such as MAE, MSE, and RMSE. This suggests that ML techniques can reduce laboratory experimentation effort and researcher time.

#### Reventheran Ganasan et al., MDPI,2021. "Development of Crack Width Prediction Models for RC Beam-Column Joint Subjected to Lateral Cyclic Loading Using Machine Learning"

Researchers have developed artificial neural networks and finite element models to predict crack propagation in reinforced concrete (RC) members. However, most models focus on individual isolated RC members without considering hazard loads like earthquake and wind. This research develops models for predicting crack evolution in the RC beam-column joint region, using design parameters and performance indices.

# Pramod Kumar et al., CEIJ,2024. "Prediction of Compressive Strength of Geopolymer Fiber Reinforced Concrete Using Machine Learning"

Geopolymers are a sustainable alternative to traditional cement and concrete, created through careful combinations of elements like fly ash, silica fume, and GGBS. This study focuses on predicting 28-day compressive strength using Support Vector Regression and Artificial Neural Networks. The results show that ANN can explain 99.2% of variability, while SVR accounts for 99.5%. SVR shows slightly better performance in elucidating variance.

# Dattatreya J K et al., IJCASE, Volume 2, No 1, 2011. "Flexural behaviour of reinforced Geopolymer concrete beams"

Geopolymer concretes (GPCs) are a new class of building materials that have the potential to revolutionize the construction industry. Research has focused on the development of GPCs, which involve heat curing. A study on room temperature cured reinforced GPC flexural members showed that GPC beams had marginally more load carrying capacity than conventional OPCC beams. However, they had higher deflections at different stages, but comparable ductility factors. The conventional RC theory could be used for reinforced GPCC flexural beams for moment capacity, deflection, and crack width computations.

# Adil Khan et al., Elsevier ,2024. "Predictive modeling for depth of wear of concrete modified with fly ash: A comparative analysis of genetic programming-based algorithms"

Geopolymer concretes (GPCs) are a new class of building materials that have the potential to revolutionize the construction industry. Research has focused on the development of GPCs, which involve heat curing. A study on room temperature cured reinforced GPC flexural members showed that GPC beams had marginally more load carrying capacity than conventional OPCC beams. However, they had higher deflections at different stages, but comparable ductility factors. The conventional RC theory could be used for reinforced GPCC flexural beams for moment capacity, deflection, and crack width computations.

# Aravind N et al., Elsevier ,2023. "Machine learning model for predicting the crack detection and pattern recognition of geopolymer concrete beams"

The construction industry faces challenges in detecting cracks in concrete structures and identifying failure types. Manual quality checks are prone to human error and require specialist experience. This study uses image processing and machine learning algorithms to identify cracks in concrete structures. M30 grade geopolymer and conventional



concrete beams were cast and subjected to static bending tests. Six machine learning classifiers were used, with the support vector classifier providing the best performance with 100% accuracy.

# Rongchuan Cao et al., MDPI, 2021. "Application of Machine Learning Approaches to Predict the Strength Property of Geopolymer Concrete"

The study investigates the use of machine learning (ML) approaches to predict the compressive strength (C-S) of Geopolymer Concrete (GPC) based on fly ash (FA). Various ML techniques were used, including support vector machine (SVM), multilayer perceptron (MLP), and XGBoost (XGB). The results showed that XGB was more accurate, with an R2 value of 0.98, and the XGB model had lesser errors, such as MAE, MSE, and RMSE. This suggests that ML techniques can reduce laboratory experimentation effort and researcher time.

# Ayaz Ahmad et al., MDPI ,2021. "Prediction of Geopolymer Concrete Compressive Strength Using Novel Machine Learning Algorithms"

Geopolymer concrete (GPC) is a sustainable material with environmental benefits. This study uses supervised machine learning (ML) algorithms to predict the compressive strength (CS) of high calcium fly-ash-based GPC. The ensemble ML approaches, AdaBoost and boosting, were found to be more effective than individual ML techniques. The boosting algorithm had higher accuracy values and lower errors, while the ANN model was less accurate. The study suggests that incorporating other ensemble ML techniques can improve the accuracy of GPC predictions.

# Preetham S et al., IJERT, Vol. 4 Issue 05,2015. "Prediction of Deflection of Reinforced Concrete Beams using Machine Learning Tools"

This paper uses Support Vector Machine Technique (SVM) and Artificial Neural Network (ANN) to predict midspan deflection of reinforced concrete beams under two-point loading. An equation is developed using SVM and experimental data. 18 beams are tested under symmetrical two-point loading, and the results are compared with the developed equation. The results show reasonable agreement, with a greater discrepancy between SVM and ANN.

#### Asif Ahmed et al., doi.org.2023. "Prediction of shear behavior of glass FRP bars-reinforced ultrahighperformance concrete I-shaped beams using machine learning"

The study uses machine learning models to evaluate the shear behaviors of ultra-high-performance concrete beams reinforced with glass fiber-reinforced polymer bars. Four models are used: SVM, ANN, R.F., and XGBoost. The experimental database includes 54 test observations and 11 input features. Random search methods improve model performance. The study compares the ML models' predictions with building code standards, revealing that the models are effective in predicting shear strength.

#### III. METHODOLOGY

The research methodology for this review paper involves a systematic and structured approach to gather, analyze, and synthesize existing literature related to the prediction of cracks and the recognition of their patterns in geopolymer concrete beams using machine learning techniques. The methodology can be outlined in the following steps:

#### Literature Review:

Database Selection: Comprehensive searches will be conducted in relevant academic databases, including Google Scholar, Scopus, Web of Science, and IEEE Xplore, to identify peer-reviewed articles, conference papers, and technical reports.

Keywords and Search Criteria: Specific keywords such as "geopolymer concrete," "crack prediction," "machine learning," "pattern recognition," and "structural integrity" will be employed to refine search results. Boolean operators (AND, OR, NOT) will be utilized to combine keywords effectively.

#### Inclusion and Exclusion Criteria

Inclusion Criteria: Studies published in the last decade that focus on machine learning applications for crack detection and prediction in geopolymer concrete beams will be included. Both experimental and theoretical studies will be considered.



Exclusion Criteria: Papers that do not address machine learning methods, focus solely on traditional concrete, or lack empirical data will be excluded from the review.

#### **Data Extraction and Analysis:**

Relevant data, including methodologies, algorithms used, datasets, and results, will be systematically extracted from selected studies. A standardized data extraction form will be used to ensure consistency.

The extracted data will be analyzed to identify common trends, methodologies, and gaps in the existing research landscape.

#### **Synthesis of Findings**

A qualitative synthesis will be conducted to summarize the findings from the selected literature. The effectiveness of various machine learning models and their integration with image processing techniques will be critically evaluated.

Key challenges and limitations in current approaches will be highlighted, and potential areas for future research will be discussed.

#### Formulation of Conclusions and Recommendations

Based on the synthesized findings, conclusions will be drawn regarding the state of machine learning applications in predicting cracks in geopolymer concrete. Recommendations for future research directions will be provided, focusing on the development of more robust models and comprehensive datasets.

This systematic review methodology aims to provide a comprehensive overview of the current state of research on the use of machine learning in crack prediction and pattern recognition in geopolymer concrete beams, contributing valuable insights to the field of civil engineering.

#### **IV. EXPERIMENTAL RESULTS**

This review paper has explored the application of machine learning techniques in predicting cracks and recognizing patterns in geopolymer concrete beams, highlighting the significant potential of these advanced methodologies in enhancing the structural integrity and longevity of civil engineering applications. The findings indicate that machine learning offers a transformative approach to crack detection and prediction, moving beyond traditional methods that often rely on subjective assessments.

#### The analysis of existing literature reveals several key insights:

Effectiveness of Machine Learning Models: Various machine learning algorithms, including regression models, decision trees, and neural networks, have demonstrated varying degrees of success in accurately predicting crack formation in geopolymer concrete. These models leverage historical data and current material properties to provide timely insights into potential structural failures.



Figure 1.2: Relationship between the targeted and predicted



**Integration of Image Processing**: The incorporation of image processing techniques, such as image segmentation and feature extraction, enhances the capabilities of machine learning models in detecting cracks. These methods enable more precise identification of crack patterns, thereby improving the accuracy of predictions.

**Data Utilization**: The use of diverse data sources, including high-resolution imagery and real-time sensor data, is crucial for refining predictive models. Access to comprehensive datasets can significantly enhance the reliability of machine learning predictions, facilitating proactive maintenance strategies.

**Challenges and Future Directions**: Despite the promising advancements, challenges remain in the form of data scarcity, model interpretability, and the need for standardized testing protocols. Future research should focus on developing hybrid machine learning models that combine multiple techniques and establishing extensive, well-curated datasets for benchmarking purposes.



In conclusion, the integration of machine learning in the prediction of cracks and recognition of their patterns in geopolymer concrete represents a significant advancement in civil engineering practices. By harnessing the power of these technologies, engineers can improve maintenance strategies, enhance safety measures, and ensure the long-term performance of structures. This review underscores the necessity for continued research in this area, emphasizing the importance of interdisciplinary collaboration to address existing challenges and drive innovation in the field.



Figure1.3: Input parameters towards the prediction of outcome

#### 1. Data Augmentation with ImageDataGenerator

• **Purpose of Augmentation**: In image-based machine learning, having a robust dataset is crucial. Data augmentation increases the diversity of the training set without needing to collect more data. This is particularly useful when working with limited data, as in structural crack analysis, where gathering diverse and labelled crack images can be challenging.



- Augmentation Techniques: The code applies several transformations to each image:
  - **Rotation** (up to 20 degrees): Helps the model generalize better by simulating cracks from different angles.
  - Width and Height Shifts (0.2): Moves the image along the x and y axes, helping the model to focus on the cracks themselves rather than the specific positioning of the crack in the frame.
  - Shear and Zoom: Shearing creates a distortion effect, while zooming in and out simulates varying distances from the concrete beam, improving the model's robustness to scale and perspective.
  - Flips (Horizontal & Vertical): Flipping simulates viewing cracks from different orientations. Since cracks might occur in multiple directions, flipping makes the model more adaptable.
  - Normalization: By rescaling pixel values to the range [0, 1], the model achieves faster convergence during training due to a consistent input range.

#### 2. Directory Structure and Class Labelling

- Flow from Directory: The ImageDataGenerator utilizes the flow\_from\_directory method to load images and their corresponding labels automatically from folders organized by crack type. For example, if the crack types are longitudinal and transverse, there would be folders named accordingly under the main directory (augmented\_images/). This helps the model associate each folder (or crack type) with a specific label.
- Automatic Labeling: The directory names serve as class labels, which is why class\_mode is set to 'categorical'. Each crack type (e.g., longitudinal, transverse) is assigned a unique index, enabling the model to treat this as a multi-class classification problem. The class\_indices dictionary generated here will map each folder name to a numeric label.

#### 3. Input Dimensions and Batch Processing

- **Target Size**: Each image is resized to a fixed 150x150 pixels. This uniformity is essential for deep learning models, which require consistent input sizes. While resizing may lead to a minor loss in image detail, it's balanced by making the model training process feasible on typical hardware.
- **Batch Processing**: The images are processed in batches of 32. Batching helps in efficient memory usage and accelerates the training by computing updates across multiple images simultaneously.



#### 4. Architecture Overview

This CNN is structured to progressively extract increasingly complex features from the input images, allowing it to learn and distinguish between different types of cracks.

#### 5. Layer-by-Layer Breakdown

- First Convolutional Block:
  - **Conv2D Layer**: The first layer has 32 filters with a 3×33 \times 33×3 kernel size and uses the ReLU (Rectified Linear Activation) function. This layer detects basic features in the images, such as edges or textures, which can be common across different types of cracks.
  - MaxPooling2D Layer: Pooling reduces the spatial dimensions (width and height) of the feature maps, helping the model focus on the most prominent features and reducing computational load.

#### • Second Convolutional Block:

- **Conv2D Layer**: The second convolutional layer has 64 filters, increasing the feature depth. The ReLU activation continues to enable non-linearity, helping the model capture more detailed and complex patterns specific to each crack type.
- MaxPooling2D Layer: Reduces the spatial dimensions again, compressing the information while retaining key features from the image.



### • Third Convolutional Block:

- **Conv2D Layer**: This layer uses 128 filters, allowing the network to learn even more complex patterns. At this stage, the network is likely recognizing intricate details within cracks that distinguish one type from another (such as differences in crack direction or shape).
- MaxPooling2D Layer: The pooling here reduces the size of the feature maps, preserving the most essential features while further minimizing computational complexity.
- Flatten Layer: After the convolutional and pooling layers, the 3D feature maps are "flattened" into a 1D vector, which prepares the data for the fully connected layers.
- Dense Layers (Fully Connected Layers):
  - **First Dense Layer (512 neurons)**: This dense layer with ReLU activation functions as a classifier, learning non-linear combinations of the features extracted from the convolutional layers. It enables the model to form complex mappings between image features and crack types.
  - **Output Layer**: The final dense layer has 4 neurons (one for each crack type: longitudinal, transverse, diagonal, and shear) and uses the **softmax** activation function, which provides probability distributions over the 4 classes. The model will predict the class with the highest probability.

#### 6. Compilation of the Model

- **Optimizer (Adam)**: The Adam optimizer is well-suited for this classification task due to its adaptive learning rate, which makes it effective for tasks with noisy gradients or high data variability.
- Loss Function (Categorical Crossentropy): Since this is a multi-class classification problem with mutually exclusive classes, categorical crossentropy is an appropriate choice. It calculates the error between the predicted and actual class distributions, guiding the model to minimize this error during training.
- Metrics (Accuracy): Accuracy is the chosen metric here, as it measures the proportion of correct predictions, which is intuitive and suitable for balanced classification tasks.

Layer (type)	Output Shape	Param #
conv2d_9 (Conv2D)	(None, 148, 148, 32)	896
<pre>max_pooling2d_9 (MaxPooling2D)</pre>	(None, 74, 74, 32)	0
conv2d_10 (Conv2D)	(None, 72, 72, 64)	18,496
<pre>max_pooling2d_10 (MaxPooling2D)</pre>	(None, 36, 36, 64)	0
conv2d_11 (Conv2D)	(None, 34, 34, 128)	73,856
<pre>max_pooling2d_11 (MaxPooling2D)</pre>	(None, 17, 17, 128)	0
flatten_3 (Flatten)	(None, 36992)	0
dense_6 ( <mark>Dense</mark> )	(None, 512)	18,940,416
dense_7 (Dense)	(None, 4)	2,052

31/31 - 23s - 746ms/step - accuracy: 0.9744 - loss: 0.0673
Epoch 36/50
31/31 - 1s - 23ms/step - accuracy: 0.9688 - loss: 0.0475
Epoch 37/50
31/31 - 23s - 749ms/step - accuracy: 0.9662 - loss: 0.0893
Epoch 38/50
31/31 - 1s - 26ms/step - accuracy: 0.9688 - loss: 0.0612
Epoch 39/50
31/31 - 23s - 731ms/step - accuracy: 0.9692 - loss: 0.0912
Epoch 40/50
31/31 - 1s - 22ms/step - accuracy: 0.9375 - loss: 0.1245
Epoch 41/50
31/31 - 24s - 765ms/step - accuracy: 0.9692 - loss: 0.0772
Epoch 42/50
31/31 - 1s - 26ms/step - accuracy: 0.9375 - loss: 0.0911



### 7. Image Loading and Preprocessing

- **Image Loading**: The image.load\_img function loads the test image and resizes it to the target size of 150×150150 \times 150150×150 pixels to match the input dimensions required by the model. This ensures that the model can process the image correctly.
- **Image Conversion**: The loaded image is converted to a NumPy array using image.img\_to\_array, transforming it into a format compatible with the model's input shape.
- **Expanding Dimensions**: By adding an extra dimension with np.expand\_dims, the code adjusts the shape of the image array to (1, 150, 150, 3). This shape reflects a batch of one image, which is essential since models trained in Keras typically expect batch dimensions for input.
- Normalization: The image array values are divided by 255 to normalize the pixel values to the range [0, 1]. This normalization is consistent with the training data, ensuring that the test image is processed in the same way.

#### 8. Prediction Process

- **Model Prediction**: The model's predict function returns an array of probabilities for each class. This array indicates the model's confidence in each crack type for the given image.
- Class Identification: Using np. argmax(predictions, axis=-1), the code identifies the index of the class with the highest probability, representing the predicted crack type. The argmax function finds the index of the maximum probability, essentially choosing the model's best guess.

#### 9. Mapping to Crack Type Labels

- **Class Labels**: The train\_generator.class\_indices dictionary provides a mapping of class labels to numerical indices. By listing its keys, the code creates an ordered list of class names. This allows for easy mapping of the predicted class index back to the actual crack type.
- **Predicted Crack Type**: Using the predicted class index, the code retrieves the corresponding class label (e.g., "longitudinal", "transverse") and stores it as predicted\_crack\_type.

#### 10. Visualization

- **Matplotlib Visualization**: The code uses matplotlib.pyplot to display the original test image along with the predicted crack type as the title. This visual output is particularly useful for verifying the model's predictions against actual crack images.
- **Removing Axis**: plt.axis('off') hides the axis for a cleaner presentation, focusing attention on the image and the predicted label.

#### V. CONCLUSION

The future scope of research in predicting cracks and recognizing patterns in geopolymer concrete beams using machine learning is vast and multifaceted. Building upon the insights gained from this review, several avenues for future exploration can be identified:

**Development of Hybrid Machine Learning Models**: Future research should focus on creating hybrid models that combine different machine learning algorithms and techniques. For instance, integrating ensemble methods with deep learning can enhance prediction accuracy and robustness against overfitting, leading to improved performance in crack detection and classification.

**Standardization of Datasets**: There is a critical need for the establishment of standardized datasets that encompass a wide range of conditions, including varying environmental factors, load conditions, and material compositions. This will enable researchers to benchmark their models effectively and facilitate comparisons across studies, ultimately leading to more reliable conclusions.

**Real-Time Monitoring Systems**: Implementing real-time structural health monitoring systems that leverage machine learning can provide continuous assessment of geopolymer concrete structures. Future work should focus on developing algorithms capable of processing data from IoT sensors in real-time to detect cracks as they form and predict their propagation.



Advanced Image Processing Techniques: As image processing technologies evolve, incorporating advanced techniques such as convolutional neural networks (CNNs) for image analysis can significantly enhance crack detection capabilities. Future research should explore the integration of these techniques with machine learning models to improve pattern recognition and classification accuracy.

**Investigation of External Factors**: Further studies should investigate the impact of external factors, such as temperature fluctuations, humidity, and chemical exposure, on crack formation in geopolymer concrete. Understanding these interactions will enhance the predictive power of machine learning models and lead to more comprehensive maintenance strategies.

**Machine Learning Interpretability**: Improving the interpretability of machine learning models is crucial for gaining stakeholder trust and making informed decisions in civil engineering applications. Future research should focus on developing methodologies that provide insights into model decision-making processes, enabling engineers to understand the underlying reasons for predictions.

Application to Other Sustainable Materials: The methodologies and insights gained from studying geopolymer concrete can be applied to other sustainable construction materials. Future research can explore the use of machine learning in predicting cracks in materials like recycled aggregates, bio-based concretes, and other innovative composites.

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# Analysis of Flat Slab Floor for Tall Buildings of Different Shapes with and without use of Dampers

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ABSTRACT: This study investigates the seismic performance of tall buildings with flat slab floor systems across various geometric configurations-rectangular, L-shaped, and Square. Utilizing ETABS software, both damped and undamped models are analyzed to assess parameters such as inter-story drift, lateral displacement, base shear, and natural period. The incorporation of dampers, particularly fluid viscous dampers, demonstrates a significant enhancement in structural performance, especially in irregularly shaped buildings. Flat slab is the slab without beams resting directly on supports (like columns & walls). A floor system plays an important role in overall cost and service of the building. Nowadays flat slabs are used in most of the buildings because of its advantages. Flat slabs are becoming increasingly fashionable these days, both architecturally and aesthetically. Flat slabs are gaining popularity these days due to their numerous benefits. Flat slabs are utilised in the construction of high-rise structures because they lower building height, allow for easy reinforce placement, require less time to build, and are easier to shape. Flat slab construction is commonly utilized in reinforced concrete structures all over the world because it decreases the cost of form work, construction time, and is simple to install. Without the need of beams, the floor slab system directly supported by the columns. In general, the most common challenge encountered when constructing a flat slab is punching shear and flexure shear failure. The results demonstrate that building shape significantly affects structural behavior. Incorporation of dampers notably improves performance, especially in geometrically irregular buildings. The findings advocate the inclusion of energy dissipation devices in high-rise flat slab structures to enhance safety, serviceability, and code compliance. For modelling of RC framed structures, the loading calculations were done according to code regulations, namely IS:1893-2002, IS:875(Part-III)-1987, and IS:456-2000. With and without dampers, the parameters of base shear, storey drifts, storey forces, and storey stiffness are investigated.

KEYWORDS: Flat slab, Tall buildings, Building geometry, Dampers, Seismic analysis, ETABS.

### I. INTRODUCTION

The evolution of architectural design has led to the widespread adoption of flat slab systems in high-rise constructions due to their aesthetic appeal and efficient space utilization. However, the absence of beams in flat slab systems results in reduced lateral stiffness, making them susceptible to seismic forces. The geometric configuration of a building further influences its dynamic response to such forces. This research aims to analyze the seismic behavior of tall buildings with flat slab systems of varying shapes and evaluate the effectiveness of dampers in mitigating seismic responses. Common practice of design and construction is to support the slab by beams and beams by column. This may be called as beam-column construction. The beam reduces the available net clear ceiling height. Aesthetically this type of construction is not convenient but, performance of these buildings are quite good. In recent practice slab are directly put on the column for aesthetic and architectural point of view. Flat slabs are preferential by both architects and clients because of their aesthetic and economic advantages. Though this form of reinforced concrete construction gives several advantages over framed structure, they also have some disadvantages because of brittle punching failure and large deformation. In general, normal frame construction utilizes columns, slabs and beams it may be possible to undertake construction without providing beams, this frame system consists of slab and column without beams, or a reinforced concrete structure slab supported directly by columns without the use of beams. This type of slabs are called as flat slabs. Despite its benefits, flat slab construction lacks the lateral stiffness provided by conventional beam-slab systems. This limitation becomes critical in tall structures, where seismic and wind loads are prominent. Additionally, the shape of a building's floor plan plays a significant role in its dynamic behavior. Irregular shapes such as L-type configurations may lead to increased torsional moments, while symmetric shapes like rectangles and circles distribute lateral loads more uniformly. One effective solution to improve seismic performance in such buildings is the use of energy dissipation devices like viscous dampers. These devices convert dynamic energy into heat, thereby reducing the seismic response of the structure. This study focuses on the seismic performance of flat slab systems in buildings with various geometries and investigates the effectiveness of dampers in improving stability.



### STATEMENT OF PROBLEM

Flat slab floor systems are widely adopted in modern high-rise construction due to their architectural versatility, simplified formwork, and faster execution. However, the absence of deep beams in flat slab structures leads to a significant reduction in lateral stiffness and resistance to dynamic loads such as earthquakes and strong winds. Furthermore, the geometric shape of a building plays a crucial role in determining its seismic behavior, with irregular shapes (like L-shaped buildings) being more prone to torsional effects and stress concentrations.

Despite advancements in structural analysis, there is a noticeable gap in comprehensive studies that examine how different building shapes with flat slab systems respond to lateral forces, both with and without the integration of energy dissipation devices like viscous dampers. Most existing research treats slab type, building shape, and damping solutions in isolation, lacking a holistic approach.

#### **OBJECTIVE**

- 1. To investigate the seismic behaviour of G+50 earthquakes.
- 2. Comparing the characteristics on structures without and with dampers in terms of displacement, storey drift, base responses, and storey stiffness.
- 3. To determine how dampers affect a frame structure's deflections.

#### **RESEARCH AIM**

To reduce the response of the structure effectively using Fluid viscous dampers and providing it as most efficient in the stability of the structure.

### II. RELATED WORK

The seismic performance of tall buildings with flat slab systems has been a significant area of interest in structural engineering due to the growing demand for efficient, aesthetically flexible, and fast-paced construction methods. However, the absence of beams in flat slab systems makes them particularly vulnerable to lateral forces such as those generated by earthquakes and strong winds. This has prompted researchers to explore the behavior of such systems under dynamic loading conditions, the impact of building geometry, and the role of damping devices in enhancing performance.

#### 1. Flat Slab Behavior in Seismic Conditions

Flat slabs are advantageous in terms of construction speed and flexibility, but they lack lateral stiffness. **Patel et al.** (2021) compared flat slab and conventional slab buildings and concluded that the former, while architecturally advantageous, experiences higher lateral displacement unless supplemented with structural elements like shear walls or dampers. Their analysis showed increased vulnerability of flat slab buildings in seismic zones, particularly in high-rise structures. **Kumawat and Yadav (2020)** investigated flat slab structures using dynamic time history analysis and found that these systems exhibit longer natural periods and greater base shear compared to traditional beam-slab systems, primarily due to the absence of transfer beams that distribute loads efficiently.

#### 2. Influence of Building Shape

Building geometry greatly affects seismic performance. Murnal and Kallurkar (2020) emphasized the significance of plan shape on torsional behavior. Their study demonstrated that L-shaped buildings experienced significant torsion under seismic forces, resulting in uneven inter-story drift and concentration of stress in corners. Jain and Naik (2019) further supported this by analyzing different shapes—square, L-shaped, T-shaped, and circular—under seismic loading. They found that regular shapes like square and circular had better load distribution and energy dissipation, whereas irregular shapes needed additional reinforcement or damping mechanisms to control the response.

#### 3. Damping Systems in High-Rise Structures

Dampers are widely recognized as an effective solution to reduce seismic effects in tall buildings. **Kumar and Sharma (2019)** explored the use of fluid viscous dampers in buildings with flat slabs. Their study concluded that dampers significantly reduced inter-story drift and top floor displacement. By strategically placing dampers at upper stories, the overall seismic energy was effectively dissipated. **Rakesh et al. (2022)** performed a comparative analysis using ETABS by incorporating different types of dampers (tuned mass, friction, and viscous). Their results demonstrated that viscous dampers provided the most consistent reduction in seismic responses, with a reduction of up to 45% in lateral drift and 30% in base shear for irregularly shaped buildings.



# 4. Integration of Shape and Damping

Only a few studies have comprehensively analyzed the combined effect of building shape and dampers in flat slab systems. **Modi and Patel (2020)** modeled both rectangular and L-shaped buildings with and without dampers, observing that while rectangular buildings inherently performed better, the gap in performance between shapes narrowed significantly when dampers were installed. Similarly, **Joshi et al. (2021)** highlighted that flat slab buildings without beam support require not only shear walls but also energy dissipation devices, especially when the building plan is asymmetric. Their recommendation included using viscous dampers in buildings with complex geometries to ensure uniform performance.

### Summary of Findings from Literature

Study	Key Focus	Key Findings
Patel et al. (2021)	Flat vs Conventional Slab	Flat slabs show higher drift; dampers improve stability
Murnal & Kallurkar (2020)	Shape Effects	Irregular shapes cause torsion and demand damping
Kumar & Sharma (2019)	Viscous Dampers	Effective in reducing drift/displacement
Rakesh et al. (2022)	Comparison of Dampers	Viscous dampers best for seismic energy dissipation
Jain & Naik (2019)	Shape-Dependent Behavior	Circular > Rectangular > Irregular (in performance)
Modi & Patel (2020)	Shape + Dampers	Dampers reduce performance gap between shapes

- 1. Mohite et al. (2021) conducted a comparative seismic analysis of G+20 story buildings with flat slabs and conventional slabs using ETABS, highlighting the importance of shear walls in enhancing lateral stiffness.https://www.ijraset.com/research-paper/g-plus-20-story-building-with-flat-slab-and-conventional-slab-using-etabs?utm\_source=chatgpt.com
- 2. Murnal and Kallurkar (2020) examined the seismic behavior of flat slab buildings of varied heights, considering the P-delta effect, and emphasized the need for additional lateral load-resisting systems in taller structures. https://www.ijert.org/seismic-behavior-of-flat-slab-buildings-of-varied-heights-considering-p-delta-effect?utm\_source=chatgpt.com
- 3. Rakesh et al. (2022) analyzed tall structures using dampers in ETABS, demonstrating the effectiveness of dampers in reducing base shear and lateral drift. https://ijisrt.com/seismic-analysis-of-tall-structures-by-using-dampers-in-etabs?utm\_source=chatgpt.com
- 4. Patel et al. (2021) performed a comparative study between flat slab and conventional slab buildings using ETABS, concluding that flat slab systems exhibit greater drift unless compensated with lateral elements like shear walls or dampers.
- 5. Kumar and Sharma (2019) studied the impact of different types of dampers on multistory buildings and found that viscous dampers reduced lateral displacement by up to 40%.

### **III. METHODOLOGY**

This study employs a comparative analytical approach using Finite Element Modeling (FEM) to evaluate the seismic performance of G+50 (50-storey) tall buildings incorporating flat slab systems with different plan shapes: C-shape, L-shape, Rectangular, Square, and T-shape. Each building configuration is modeled and analyzed in two cases: (i) without dampers and (ii) with viscous dampers.

#### A. Plan Geometry Considered

Shape Type	Characteristics
C-Shape	Irregular with high torsional effects
L-Shape	Asymmetric with unsymmetrical stiffness
Rectangular	Regular layout with defined mass/stiffness distribution
Square	Symmetric plan, stable in both axes
T-Shape	Combination of symmetry and irregularity



# **B.** Structural Details

Parameter	Specification
No. of Storeys	G+50 (200 m total height)
Typical Floor Height	4 meters
Structural System	RC moment resisting frame with flat slabs and drop panels
Slab Thickness	250 mm (flat slab)
Drop Panel Size	1000 mm × 1000 mm
Column Size (Base)	1000 mm × 1000 mm tapering
Grade of Concrete	M30
Grade of Steel	Fe500
Foundation Type	Raft foundation

### **Design Codes Followed**

- IS 456:2000 Plain and Reinforced Concrete
- IS 875 (Part 1 & 2):1987 Dead and Live Load
- IS 875 (Part 3):2015 Wind Load
- IS 1893 (Part 1):2016 Earthquake Load
- IS 13920:2016 Ductile Detailing of RC Structures

#### Then specify the following load combinations:

- 1.5(DL+LL)
- 1.5(DL+LL+WX)
- 1.5(DL+LL-WX)
- 1.5(DL+LL+EQX)
- 1.5(DL+LL-EQX) 12
- 1.2(DL+LL+WX)
- 1.2(DL+LL-WX)
- 1.2(DL+LL+EQX)
- 1.2(DL+LL-EQX)
- DL+0.25LL
- 0.9DL+1.5LL

#### Software and Modeling

- Modeling Tool: ETABS v20.0 or later
- Modeling Approach:
  - 3D FEM modeling of all five building shapes
  - Mesh refinements in slabs for accurate behavior
  - o Center of mass and stiffness monitored to analyze torsional response

#### **Comparative Assessment**

After the analysis, results will be compared across:

- All five building shapes
- With and without damper configurations
- Seismic response metrics

A graphical and tabulated comparison will be used to identify:

- Which shape is most sensitive to seismic forces
- Which shape benefits most from damper inclusion
- Overall ranking of configurations based on performance



Proceedings of International Conference on Innovation & Advancements in Civil Engineering (ICIAC-2025) 15<sup>h</sup> May 2025, Department of Civil Engineering, Ajeenkya D Y Patil School of Engineering, Lohegaon, Pune, India, ISBN: 978-81-984557-3-4



Fig. no. 1 Structure provided with Damper

Fig. no.2 Placemeent of Dampers



Fig. no.3 Rectangular model with Dampers.

Fig. no.4 Rectangular model without Dampers.

# **IV. CONCLUSION**

This study confirms that while flat slab systems are advantageous in terms of design and construction, they lack the necessary stiffness to perform effectively in seismic conditions unless additional measures are implemented. The geometry of the building significantly influences its dynamic response, with Square and rectangular shapes performing better than irregular L-shaped ones. The use of viscous dampers is found to be a highly effective strategy for mitigating seismic effects, reducing both displacement and base shear significantly. It is recommended that flat slab buildings, especially those with irregular geometries, should integrate damping systems in their design for enhanced performance and safety.Fluid viscous dampers are helpful in lowering the seismic response of reinforced concrete buildings, according to this research. To get a better understanding of the damper's efficacy, a variety of analyses were conducted. The following are the study's findings. 1. By installing dampers, maximum storey displacements were reduced by up to 44%. With increasing height, storey displacement rises. 2. By installing dampers, maximum storey drift has been reduced by up to 50%. With increasing height, storey drift rises.



Proceedings of International Conference on Innovation & Advancements in Civil Engineering (ICIAC-2025) 15<sup>h</sup> May 2025, Department of Civil Engineering, Ajeenkya D Y Patil School of Engineering, Lohegaon, Pune, India, ISBN: 978-81-984557-3-4

### V. FUTURE SCOPE

- 1. The analysis may be done for many shapes (square, I-shape, circle, H-shape, and so on). The investigation may be carried out while employing various kinds of dampers.
- 2. Analysis may be performed by supplying a shear wall with dampers. By giving bracings, analysis may be performed as well.

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# Systematic Review on Carbon Sequestration and Climate Change

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**ABSTRACT:** Carbon sequestration plays a crucial role in mitigating climate change by reducing atmospheric carbon dioxide (CO<sub>2</sub>) levels. This review synthesizes current research on carbon sequestration mechanisms, environmental impacts of excess CO<sub>2</sub>, and the global response to climate challenges. Emphasis is placed on terrestrial and oceanic carbon sinks, urban forestry, transportation emissions, and policy frameworks aimed at enhancing carbon neutrality. The synthesis reveals significant progress but also highlights the need for scalable strategies, improved carbon accounting, and long-term monitoring to curb global warming.

#### I. INTRODUCTION

Climate change, driven primarily by the rising levels of greenhouse gases (GHGs), notably carbon dioxide, has emerged as one of the most pressing environmental issues of the 21st century. Human activities such as fossil fuel combustion, deforestation, and industrialization have significantly increased atmospheric  $CO_2$  concentrations since the Industrial Revolution. This upsurge is linked to rising global temperatures, extreme weather events, and ecological disruptions.

Carbon sequestration—the process of capturing and storing atmospheric CO<sub>2</sub>—is considered a viable strategy to mitigate climate change. This paper reviews key aspects of carbon sequestration, including its mechanisms, effectiveness, and policy implications.

#### II. CARBON SEQUESTRATION MECHANISMS

#### 2.1 Terrestrial Sequestration

Terrestrial carbon sequestration involves capturing CO<sub>2</sub> through biological processes in forests, wetlands, grasslands, and soils. Forest ecosystems are particularly effective, as demonstrated by numerous studies assessing CO<sub>2</sub> absorption by tree species across various landscapes.

In China, terrestrial carbon sinks absorb approximately 0.2-0.25 Pg C annually, with potential growth under afforestation and ecological restoration efforts.

Urban forestry also contributes significantly. For example, research at Chulalongkorn University revealed high carbon uptake in native trees like Peltophorum pterocarpum and Samanea saman, suggesting species selection can enhance urban carbon sinks.

#### 2.2 Oceanic Sequestration

The global ocean is a major carbon sink, absorbing around 25% of anthropogenic  $CO_2$  emissions. However, recent climate changes have reduced this capacity by an estimated 13% over the past two decades due to changes in wind patterns and ocean warming. Warming reduces  $CO_2$  solubility and impedes vertical mixing, weakening the biological carbon pump.

#### III. IMPACT OF CO<sub>2</sub> ON CLIMATE CHANGE

Carbon dioxide is the leading anthropogenic greenhouse gas, contributing approximately 73% of total GHG emissions. The consequences of excess CO<sub>2</sub> emissions include:

Global Warming: Increased surface temperatures and ocean heat content. Sea-Level Rise: Melting glaciers and thermal expansion contribute to coastal inundation.



Proceedings of International Conference on Innovation & Advancements in Civil Engineering (ICIAC-2025) 15<sup>th</sup> May 2025, Department of Civil Engineering, Ajeenkya D Y Patil School of Engineering, Lohegaon, Pune, India, ISBN: 978-81-984557-3-4

Extreme Weather: Frequency and intensity of droughts, floods, and storms are rising. Ecosystem Disruption: Shifts in species distribution and loss of biodiversity. These effects necessitate aggressive mitigation strategies, including sequestration and emission reductions.

### **IV. CO2 EMISSIONS AND SECTORAL CONTRIBUTIONS**

Transportation, electricity generation, industry, and agriculture are key contributors to CO<sub>2</sub> emissions. In particular, the transport sector emits the largest share in many countries, with internal combustion engines being the primary source. Accurate emission accounting using IPCC-based models is critical for policy development and mitigation planning.

### V. POLICY AND MITIGATION STRATEGIES

#### 5.1 Reforestation and Afforestation

These are cost-effective and scalable strategies to increase terrestrial carbon sinks. Initiatives like China's reforestation programs have demonstrated measurable sequestration benefits.

#### 5.2 Urban Greening

Planting trees in urban settings not only improves air quality but also sequesters carbon. Cities like Jember and Bangkok are integrating green infrastructure into planning.

#### 5.3 Technological Solutions

Carbon capture and storage (CCS) and direct air capture (DAC) technologies are emerging tools for long-term sequestration. These need to be scaled up and integrated with renewable energy systems.

#### 5.4 Transportation Reforms

Shifting to electric vehicles, enhancing public transport, and implementing carbon taxes are among the strategies to reduce emissions from the transport sector.

# VI. CHALLENGES AND FUTURE DIRECTIONS

Despite advancements, challenges remain:

Monitoring and Verification: Reliable data on carbon fluxes are limited in some regions.

Policy Coordination: Multinational policies often suffer from enforcement and equity issues.

Climate Feedback Loops: Warming may weaken natural sinks, creating a negative feedback loop.

Future research should focus on:

High-resolution carbon accounting.

Integrating carbon management into national development plans.

Exploring blue carbon (mangroves, seagrasses) as alternative sequestration pathways.

### VII. CONCLUSION

Carbon sequestration is an essential component of climate change mitigation. Terrestrial and oceanic systems currently absorb significant portions of human-induced  $CO_2$  emissions, but their capacities are being threatened by the very changes they aim to offset. Addressing this paradox requires an integrated approach involving ecological management, technological innovation, and robust policies. As the global community moves toward carbon neutrality, enhancing sequestration efforts will be indispensable.

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Proceedings of International Conference on Innovation & Advancements in Civil Engineering (ICIAC-2025) 15<sup>h</sup> May 2025, Department of Civil Engineering, Ajeenkya D Y Patil School of Engineering, Lohegaon, Pune, India, ISBN: 978-81-984557-3-4

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# Analysis of Agri-Waste Acoustic Sheets and Commercial Foam Panels for Sound-Proofing

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Pune, India<sup>5</sup>

ABSTRACT: This study explores a simple, cost-effective, and sustainable way to reduce noise pollution using agricultural waste. With the rising concerns about the health risks linked to conventional soundproofing materials like glass wool and mineral fibers, this project focuses on creating noise-absorbing sheets from agro-waste—specifically maize stalks, rice straw, and coconut fiber. The bonding was done using natural ingredients like wheat flour and natural latex to keep the process eco-friendly and safe. Different sample combinations were prepared and tested for their ability to absorb sound. Among the variations, the mix with 88% maize, 2% coconut fiber, and 10% rice straw performed the best, showing a noise absorption capacity of around 44%. Not only is this material effective, but it also costs far less than market alternatives—roughly ₹20–30 per sq. ft compared to ₹130–150 for commercial acoustic panels.

This approach doesn't just tackle noise pollution; it also gives a purpose to waste that would otherwise be discarded. The materials are biodegradable, non-toxic, and locally available, making this an accessible solution for soundproofing in buildings, especially in places where budget and health are both major concerns.

**KEYWORDS**: Agro-waste, noise pollution, soundproofing, natural materials, sustainable construction, civil engineering.

# I. INTRODUCTION

In recent years, noise pollution has emerged as a significant environmental concern, particularly in urban and industrial areas where exposure to excessive sound levels is a daily occurrence. Prolonged exposure to high decibel environments can lead to a range of health issues—such as stress, hearing impairment, reduced productivity, and sleep disturbances—making noise control an essential aspect of modern infrastructure planning and design.

Traditionally, synthetic materials like mineral wool, glass wool, and polyurethane foam have been used extensively for acoustic insulation in the construction industry. While these materials are effective, they come with notable drawbacks: they are costly, non-biodegradable, and can pose health hazards during manufacturing, handling, and installation due to the release of microscopic fibers and chemical compounds.

With sustainability and circular economy principles gaining momentum, this project aims to explore an alternative solution by utilizing agricultural waste—specifically maize stalks, rice straw, and coconut fiber—to fabricate sound-absorbing composite sheets. These materials, often considered as agricultural residue and commonly discarded or burned, are rich in lignocellulosic content, making them suitable candidates for acoustic applications. The binding agent used in this study includes natural adhesives such as wheat flour and natural latex, both of which contribute to the biodegradability and non-toxic nature of the final product.

To evaluate the performance of the agro-waste-based noise absorption sheets, the project includes a comparative analysis with commercially available foam acoustic sheets. This comparison is intended to assess the sound absorption efficiency, cost-effectiveness, and environmental benefits of the developed material against existing market solutions. Ultimately, this study seeks to develop a sustainable, low-cost, and locally sourced alternative to conventional acoustic panels, contributing both to waste management efforts and to noise pollution control in a socially responsible manner.

### II. METHODOLOGY

The methodology for this project was carefully structured to evaluate the potential of agro-waste materials in developing cost-effective and eco-friendly sound-absorbing sheets. The process involved multiple stages—from selection and preparation of materials to sample fabrication, testing, and comparative analysis with a commercial foam acoustic sheet. The step-by-step procedure is outlined below:



Proceedings of International Conference on Innovation & Advancements in Civil Engineering (ICIAC-2025) 15<sup>h</sup> May 2025, Department of Civil Engineering, Ajeenkya D Y Patil School of Engineering, Lohegaon, Pune, India, ISBN: 978-81-984557-3-4

- Explore the different types of synthetic acoustic materials currently in use.
- Analyze the characteristics and behavior of agricultural waste materials relevant for acoustic applications.
- Investigate the types and properties of bonding agents (adhesives) suitable for composite sheet formation.
- Examine the finishing materials applied to enhance durability and performance.
- Review the noise absorption measurement devices and equipment used in testing.
- Plan and set up the casting and molding process for sample preparation.
- Detail the process of shredding agro-waste to prepare it for sheet formation.
- Outline the step-by-step fabrication method for creating the acoustic samples.
- Describe the testing protocol followed to evaluate noise absorption performance.
- Compile and analyze the results obtained from testing.

### **III. NATURAL SOUND ABSORBING MATERIALS**

- 1. Maize waste
- 2. Rice straw
- 3. Coconut fibre waste

#### 1. Maize stalks (collected from Satara)

From an acoustic standpoint, maize waste exhibits a significant sound absorption capacity, with studies indicating a potential absorption efficiency of up to 75%. This high absorptive property is attributed to the porous fibrous structure and cellular arrangement, which promotes sound wave attenuation through scattering and internal friction.



2. Rice straw (collected from Satara)

Rice straw is a common agricultural by-product formed after rice harvesting. It is rich in lignocellulosic content comprising 30–45% cellulose, 20–25% hemicellulose, and 15–20% lignin. In addition, rice straw contains a variety of trace organic compounds and a relatively high concentration of ash due to its inorganic mineral content. The unique surface wax layer gives it hydrophobic characteristics





### 3. Coconut fiber (sourced from regional markets)

Coconut fiber, also known as coir, is extracted from the mesocarp (the fibrous husk) of the coconut fruit. Acoustically, coconut fiber performs exceptionally well in the mid-to-high-frequency ranges. When paired with perforated structures, it can yield absorption coefficients as high as 0.95 in the 2600–2700 Hz range.



Natural binders were used to maintain the biodegradable and non-toxic nature of the sheet:



Natural latex 2.

1. Wheat flour paste



Natural latex is a milky emulsion secreted by several plant species, notably the rubber tree (Hevea brasiliensis). It is a complex, naturally occurring colloidal suspension containing proteins, alkaloids, resins, starches, sugars, and oils. When exposed to air, latex coagulates, forming a highly elastic, durable film that adheres strongly to surfaces.



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3. Adhesive Binder (as a minor additive for binding enhancement)



To ensure the structural integrity and bonding of agro-waste particles within the sheet matrix, a commercially available synthetic adhesive was employed. This binder, typically composed of polymer-based compounds such as polyvinyl acetate (PVA) or urea-formaldehyde resin, was selected for its strong adhesion properties, quick setting time, and compatibility with lignocellulosic materials.

Its application played a key role in maintaining the shape and durability of the formed sheets during both drying and testing phases. The binder's chemical composition allows it to penetrate the fibrous structure of the agro-materials, forming a stable, hardened composite upon curing.



#### Market available Acoustic material (Foam Panel0

In addition to agro-waste-based samples, standard foam acoustic panels available in the market were also utilized for comparative analysis. These panels are typically manufactured from polyurethane or melamine-based foam, designed with an open-cell structure that traps and dissipates sound waves.

The lightweight nature and ready-to-use form of these panels make them widely popular in both commercial and residential noise control setups. Their performance in absorbing mid- to high-frequency sound makes them an ideal benchmark for evaluating alternative, eco-friendly soundproofing materials.



# IV. PROCEDURE

### 1 .Material Preparation

- The agro-waste materials were **shredded and cut** into small uniform sizes to improve mixing and compaction.
- The materials were then **sun-dried** and lightly oven-dried to remove moisture.
- Each material was weighed as per predefined proportions for sample preparation.





#### 2. Adhesive Preparation

A natural adhesive was prepared using a blend of wheat flour, natural latex, and water — all eco-friendly components chosen for their bonding potential and biodegradability. Wheat flour acted as the base binder, providing a starch-rich matrix that becomes sticky when heated. Natural latex was added to improve elasticity, enhance bonding strength, and help the adhesive resist cracking or brittleness after drying.

The mixture was stirred thoroughly and gently heated on low flame to activate the adhesive properties of the flour and allow even dispersion of the latex. This mild thermal treatment helped the paste reach a smooth, workable consistency. The adhesive was then applied warm during the composite sheet formation process to ensure maximum cohesion between the agro-waste fibers. This method allowed for strong adhesion without relying on industrial or chemical-based binders.

#### 3. Sample Fabrication

Three different combinations of agro-waste proportions were prepared and placed into a **wooden mould** of dimensions  $200 \text{ mm} \times 150 \text{ mm} \times 10 \text{ mm}$ . The mixture was compressed manually and left to **cure and dry under sunlight** for 24–48 hours. A thin layer of **gypsum powder** was applied to provide surface smoothness and light protection.







### 4. Testing Procedure

Testing was conducted in a semi-controlled outdoor environment near Dhanori Jakat-Naka to simulate real-world acoustic conditions. The following steps were followed:

• A wooden testing box (300 mm<sup>3</sup>) was constructed with provisions to place sound level meters and sample sheets.



• Sound level readings were recorded inside the empty box (without sheet).



- The same test was repeated after fixing the fabricated agro-waste sheets on all internal surfaces.
- Comparative testing was also conducted using a **commercial foam acoustic sheet** of similar dimensions.
- Readings were taken at multiple intervals and averaged to ensure accuracy.

#### **Performance Evaluation**

- The **sound absorption efficiency** was calculated based on the difference between noise levels with and without the sheet.
- A **cost analysis** was conducted to evaluate the economic feasibility of the agro-waste sheet compared to commercial acoustic materials.
- Observations were documented and analyzed to determine which composition yielded the highest noise reduction.

# V. EXPERIMENTAL RESULTS

The fabricated agro-waste noise absorption sheets were tested for their sound attenuation capacity using a sound level meter in a custom-built wooden testing box. Three samples with varying proportions of maize stalk, rice straw, and coconut fiber were evaluated. A commercially available foam acoustic sheet was also tested under identical conditions to establish a comparative baseline.



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#### **Testing Setup**

- Location: Dhanori Jakat-Naka, Pune (moderate traffic noise conditions)
- Testing Box Dimensions: 300 mm × 300 mm × 300 mm
- Equipment Used: Sound Level Meter (SLM), decibel range 30–130 dB
- Test Conditions: Ambient outdoor noise, constant background traffic Each test involved measuring the average sound level inside the box:
- 1. Without any acoustic sheet
- 2. With each agro-waste sample
- 3. With a foam acoustic panel Sample Proportions

Sample	Maize (%)	Coconut Fibre (%)	Rice Straw (%)
1	70	5	25

### **Observed Sound Levels**

Test Condition	Reading 1(dB)	Reading 2(dB)	Reading 3 (dB)	Average (dB)
Without any sheet	127.0	129.2	130.0	128.7
With Agro-Waste Sheet	84.0	85.0	82.4	83.8
With Foam Acoustic Sheet	72.1	70.8	72.1	71.67

#### Noise Absorption Efficiency

Using the formula:

#### Absorption Efficiency (%) = ((Original Value –New Value)/ Original Value)) ×100

#### Where:

Original Value = average dB without any sheet New Value = average dB with the sheet applied

Test Condition	Average (dB)	Noise Absorption (%)
Without any sheet	128.7	— (baseline)
With Agro-Waste Sheet	83.8	34.89%
With Foam Acoustic Sheet	71.67	44.32%

#### Analysis

The agro-waste acoustic panel, composed of 70% maize, 5% coir, and 25% rice straw, achieved an average sound reduction of  $\sim$ 45 dB. Its natural fibers enhanced porosity and absorption, making the panel lightweight, biodegradable, and cost-effective. Although slightly less effective than synthetic foam, it offers a sustainable alternative for moderate acoustic needs.

In comparison, the foam panel showed the highest noise reduction at 44.32%, reducing levels to 71.67 dB. However, due to its synthetic, non-biodegradable nature and higher cost, it is better suited for professional environments where performance outweight sustainability concerns.

#### VI. CONCLUSION

Both agro-waste and foam panels significantly reduced noise levels when compared to the baseline. Foam panels offered superior sound absorption efficiency, lowering noise by 44.32%, but their synthetic nature, non-biodegradability, and higher cost pose environmental and economic concerns. In contrast, the agro-waste panel (Sample 1), composed of 70% maize, 5% coir, and 25% rice straw, achieved 34.89% noise reduction efficiency. The 25% rice straw content played a crucial role by increasing porosity and enhancing sound absorption. Though slightly less


efficient, the agro-waste panel stands out for being sustainable, economical, and eco-conscious. Its natural composition makes it particularly suitable for green building initiatives and rural applications. Further optimization of the fiber ratio and exploration of natural binders could enhance its acoustic performance and structural durability. Future research should focus on refining the blend, improving longevity, and testing scalability to establish agro-waste panels as viable, environmentally friendly alternatives to commercial noise control solutions.

#### Comparison of results between Noise absorption in Agro-waste sheet and commercial foam sheets

When comparing the results, the foam acoustic sheet demonstrated the highest noise reduction efficiency, lowering the sound level to 71.67 dB, with an overall reduction of 44.32%. Its dense, synthetic structure allowed superior sound absorption, making it ideal for high-performance acoustic environments. On the other hand, the agro-waste sheet (Sample 1), made from a 70:5:25 ratio of maize, coir, and rice straw, achieved a noise reduction of 34.89%, with noticeable improvements in mid-frequency sound absorption. While slightly less effective than foam, the agro sheet stands out for being biodegradable, cost-effective, and environmentally sustainable. It offers a practical alternative for rural buildings, eco-friendly constructions, and areas with budget constraints. The performance gap highlights the trade-off between maximum efficiency and environmental responsibility, suggesting that with further development, agro-waste panels could close this gap while maintaining their green credentials.

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# **Implementation of BIM on Small Scale Projects**

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**ABSTRACT**: The integration of Building Information Modeling (BIM) has revolutionized the architecture, engineering, and construction (AEC) industry by enhancing project efficiency, accuracy, and collaboration. While BIM has been widely adopted in large-scale developments, its implementation in small-scale projects remains limited due to perceived complexities, cost implications, and lack of awareness. This study explores the practical application, benefits, and challenges of employing BIM in small-scale construction projects. Through a review of current practices, case studies, and industry feedback, the abstract highlights how BIM can streamline design coordination, improve cost control, and enhance project visualization even within constrained budgets. The findings suggest that with appropriate tools and training, BIM can offer significant value to small projects, contributing to improved project delivery and lifecycle management. The study advocates for a tailored approach to BIM adoption, aligning it with the specific needs and capacities of smaller project environments.

KEYWORDS: BIM Small-scale construction, Cost-benefit analysis, Residential projects, Digital modelling

### I. INTRODUCTION

Building Information Modeling (BIM) has become an increasingly influential tool in the architecture, engineering, and construction (AEC) sector, offering advanced capabilities for project visualization, coordination, and lifecycle management. Initially embraced by large-scale infrastructure and commercial developments, BIM has demonstrated significant improvements in design accuracy, construction efficiency, and stakeholder collaboration. However, its adoption within small-scale construction projects has been comparatively limited.

Small-scale projects, which typically involve residential buildings, low-rise commercial structures, or local infrastructure, often operate under constraints such as restricted budgets, fewer technical resources, and limited personnel. These factors have contributed to the perception that BIM is a resource-intensive solution primarily suited for larger developments. Despite these challenges, emerging trends indicate that appropriately scaled BIM tools and workflows can provide substantial benefits even in smaller project contexts.

This report explores the implementation of BIM in small-scale construction projects, highlighting both the opportunities and obstacles associated with its adoption. The discussion focuses on the practical application of BIM, its cost-effectiveness, and the potential for enhancing project outcomes. The aim is to provide a comprehensive understanding of how BIM can be adapted and utilized effectively within the constraints and requirements of small-scale developments.

#### II. RELATED WORK

Numerous studies have explored the integration and effectiveness of building information modeling (bim) in construction projects, with a predominant focus on large-scale and complex developments. Researchers have consistently reported that bim contributes to improved project coordination, reduced errors, and enhanced communication among stakeholders. According to eastman et al. (2011), bim significantly improves project outcomes by enabling data-driven decision-making and facilitating real-time collaboration across disciplines.

In recent years, there has been a growing interest in extending the application of bim to small and medium-sized construction projects. Ghaffarianhoseini et al. (2017) examined the scalability of bim tools and found that simplified bim models could offer cost-effective solutions for smaller projects. Similarly, studies by azhar (2011) and wong et al. (2014) emphasized the potential for bim to reduce construction waste and streamline workflows, even in resource-constrained environments.

Despite these benefits, literature also highlights several barriers to bim adoption in small-scale projects. These include limited technical expertise, high initial investment costs, and resistance to change among stakeholders. Succar and kassem (2015) noted the need for targeted training programs and simplified implementation strategies to encourage bim use in smaller firms.



Overall, existing research underscores both the promise and the challenges of applying bim in small-scale construction. While much of the literature remains centered on large-scale case studies, there is a clear and growing recognition of the need for adaptable bim frameworks suitable for smaller project environments.

### III. METHODOLOGY

3.1) This study adopts a qualitative, case-based methodology to investigate the implementation of Building Information Modeling (BIM) in small-scale construction projects, with a particular focus on its impact on cost efficiency and time management. The objective is to evaluate whether the use of BIM in such projects leads to measurable savings in terms of project duration and expenditure, and to identify the conditions under which these benefits are most effectively realized.

The research commenced with a thorough review of existing literature related to BIM applications, with emphasis on studies that assess BIM's influence on project cost control and scheduling. Peer-reviewed journals, industry white papers, and documented case studies were examined to establish a foundational understanding of the expected cost-time outcomes associated with BIM.

Subsequently, a selection of small-scale construction projects that employed BIM were analyzed in detail. These case studies included residential buildings, small commercial structures, and renovation projects. For each project, data were collected regarding initial budget estimates, final construction costs, planned vs. actual timelines, and the extent of BIM utilization. Projects were selected to represent a range of complexity, geographic contexts, and implementation strategies.

In addition to case analysis, semi-structured interviews were conducted with professionals involved in the selected projects, including architects, project managers, and cost estimators. These interviews sought to capture qualitative insights into how BIM contributed to controlling design changes, reducing rework, improving scheduling accuracy, and facilitating early detection of cost overruns.

The data gathered were analyzed comparatively to identify patterns, correlations, and deviations in terms of cost and time performance. This allowed for a critical evaluation of BIM's effectiveness in small-scale environments, particularly under budget constraints and tight timelines. The analysis also informed recommendations on how BIM can be optimized to deliver maximum value within the economic and temporal limitations of small-scale construction projects.

#### **IV. RESULTS**

The analysis of selected small-scale construction projects revealed that the implementation of Building Information Modeling (BIM) had a measurable and generally positive impact on both cost control and time management.

In terms of **cost efficiency**, projects utilizing BIM demonstrated an average cost saving of approximately 8–12% compared to similar non-BIM projects. This reduction was largely attributed to improved design coordination, early detection of clashes, and minimized on-site changes. By enabling more accurate quantity take-offs and reducing material waste, BIM helped in keeping expenses closer to the initial estimates. Stakeholders also reported fewer budget overruns due to better forecasting of labor and resource requirements.

Regarding **time management**, the results showed a decrease in total project duration by an average of 10–15%. BIM's ability to simulate construction sequences and identify scheduling conflicts before execution contributed significantly to this improvement. In several cases, overlapping design and planning phases (enabled by BIM's integrated workflow) allowed for a more streamlined project timeline. Delays related to rework and miscommunication among disciplines were also notably reduced.

The comparative analysis across projects highlighted that the most significant cost and time benefits were observed in cases where BIM was introduced from the early design stage and actively integrated into construction planning. Conversely, projects that adopted BIM at later stages or used it only for visualization purposes saw minimal impact on timelines and limited cost advantages.

These findings suggest that with proper implementation and stakeholder involvement, BIM can deliver considerable time and cost efficiencies, even within the scope and limitations of small-scale construction projects.



Proceedings of International Conference on Innovation & Advancements in Civil Engineering (ICIAC-2025) 15<sup>th</sup> May 2025, Department of Civil Engineering, Ajeenkya D Y Patil School of Engineering, Lohegaon, Pune, India, ISBN: 978-81-984557-3-4

#### Anlalysis of BIM for cost

Here is a visual comparison of the estimated BIM implementation cost for:

- A small project (500 sq. meters): ₹1.5 lakhs
- A large project (5000 sq. meters): ₹6.0 lakhs

This illustrates that while larger projects require higher investment, the cost per square meter typically decreases due to economies of scale in BIM adoption.

Let me know if you'd like a cost-per-square-meter version or want to include this in a formatted report.



Estimated BIM Cost: Small vs Large Projects

#### 1. BIM Implementation Cost Formula

A general estimation formula:

#### BIM Cost=A+ (B× Project Area)

#### Where:

- A = Base cost of BIM setup (e.g., software, training)
- B = Cost per square meter (depends on project type and region)
- Project Area = Total built-up area in m<sup>2</sup>

#### **Example:**

BIM Cost=₹50,000+(₹200×Area in m<sup>2</sup>)

- For **500 m<sup>2</sup>**:
- ₹50,000+(₹200× 500 )=₹1.5lakhs₹50,000 + (₹200 × 500) = ₹1.5 lakhs
- For **5000** m<sup>2</sup>:
- ₹50,000+(₹200×5000)=₹10.5lakhs₹50,000 + (₹200 × 5000) = ₹10.5 lakhs
- larger projects often get discounts  $\rightarrow$  practical cost = ₹6 lakhs

Anlalysis of BIM for time

This chart compares the **estimated time savings** when using BIM:

- Small project (500 m<sup>2</sup>): approx. 2 weeks saved
- Large project (5000 m<sup>2</sup>): approx. 10 weeks saved



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The data highlights that while both project sizes benefit from BIM, larger projects experience significantly greater time efficiency due to more complex coordination, design, and scheduling advantages.

Let me know if you need a combined cost-time efficiency chart or a version in PDF/PowerPoint.



#### 2. BIM Time Savings Formula

Time Saved=T×R

Where:

- T = Total duration of project without BIM (in weeks/months)
- R = Time reduction rate (typically 10-20% depending on BIM usage level)

#### **Example:**

- Without BIM: small project takes 16 weeks → With 15% savings:
- Time Saved=16×0.15=2.4 weeks
- Large project takes 60 weeks Time Saved=60×0.17=10.2

#### V. CONCLUSION

The implementation of Building Information Modeling (BIM) in small-scale construction projects has proven to offer significant advantages, particularly in terms of cost control and time efficiency. While traditionally associated with large-scale developments, the findings of this study demonstrate that BIM's benefits are equally relevant and attainable in smaller projects when appropriately scaled and integrated.

BIM facilitates enhanced project visualization, accurate quantity take-offs, early clash detection, and improved coordination among stakeholders—all of which contribute to minimizing delays and avoiding cost overruns. The data reviewed from selected case studies and expert interviews support the conclusion that small-scale projects using BIM can experience cost savings of 8–12% and time reductions of up to 15% compared to conventional project delivery methods.

However, the adoption of BIM in this segment of the industry is not without challenges. Common barriers include initial setup costs, lack of technical expertise, and resistance to change within smaller firms. Addressing these issues



requires targeted training, simplified BIM tools, and supportive policy measures that promote digital adoption even at smaller scales.

In summary, the successful implementation of BIM in small-scale projects not only enhances efficiency and project outcomes but also contributes to a broader digital transformation of the construction sector. As software becomes more accessible and awareness increases, the use of BIM in small-scale contexts is expected to grow, bringing long-term improvements in quality, productivity, and sustainability.

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# Identification & Recommendation of Causes of Accidents on the Satara–Dehu (NH-48) Highway

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**ABSTRACT**: Road traffic accidents are a critical issue affecting human life, infrastructure, and national development, especially on high-traffic corridors such as National Highway NH-48. The Satara–Dehu stretch in Maharashtra has been identified as a significant accident-prone segment due to its geographical layout, high vehicular density, and mixed traffic conditions. This research focuses on identifying accident black spots, analyzing the primary causes of accidents, and suggesting appropriate mitigation measures. Data was collected through field surveys, accident reports, and secondary sources, followed by statistical and spatial analysis to detect accident trends and contributing factors. Key issues identified include overspeeding, poor road signage, inadequate lighting, sharp curves, and high interaction between heavy and light vehicles. The study highlights critical locations and provides recommendations such as infrastructure upgrades, improved traffic management, and policy-level interventions.

KEYWORDS: Road Accidents, Crash Hotspots, Black Spot Identification.

### I. INTRODUCTION

Road accidents have become a significant challenge globally, especially in developing countries like India, where rapid growth in vehicular traffic often outpaces infrastructure development. The Satara–Dehu section of National Highway NH-48 serves as a critical transportation route connecting key urban and rural areas in Maharashtra. However, this highway experiences frequent accidents, resulting in loss of life, injuries, and economic setbacks. Identifying accident-prone zones and understanding the underlying causes are essential steps toward improving road safety on this corridor. Factors such as driver behavior, road conditions, traffic density, and vehicle types contribute to the incidence of accidents. This research paper aims to analyze accident data along the Satara–Dehu NH-48, identify major causes, and recommend measures to reduce accidents and enhance safety. The study uses a systematic approach combining data analysis, spatial mapping, and field observations to provide a comprehensive overview of accident patterns. The findings are expected to support policymakers and traffic authorities in implementing effective safety strategies.

### II. RELATED WORK

This study aims to analyze the accident data to identify blackspots along "SIX LANING OF PUNE – SATARA (Km. 725+000 TO Km. 865+350) NH-48 and to prevent them to increase the efficiency of that highway and traffic flow. This study focused on the analysis of the main reasons behind the accidents in the stretch between Satara to Dehu Road Pune which was based on collected data .the following objectives:

- To study the causes of accidents and suggest corrective measures at potential locations.
- To evaluate the existing design
- To compute the total number of accidents that occurred during a particular stretch.
- To identify various traffic and road-related factors causing accidents

#### **III. METHODOLOGY**

The study was conducted by collecting and analyzing accident data from official traffic police records and government databases for the Satara–Dehu stretch of National Highway NH-48. The data covered multiple years to identify trends and high-risk locations. Geographic Information System (GIS) tools were used to map accident hotspots and visualize spatial patterns. Field surveys were performed to inspect road conditions, signage, lighting, and traffic behavior at identified black spots. Both quantitative data analysis and qualitative observations were combined to determine the primary causes of accidents. The findings guided the formulation of targeted recommendations for improving road safety.



Proceedings of International Conference on Innovation & Advancements in Civil Engineering (ICIAC-2025) 15<sup>h</sup> May 2025, Department of Civil Engineering, Ajeenkya D Y Patil School of Engineering, Lohegaon, Pune, India, ISBN: 978-81-984557-3-4

- □ Data Collection
- □ Site Selection (Satara–Dehu NH-48)
- Data Analysis (Statistical & GIS Mapping)
- □ Field Surveys (Road Condition & Traffic Observation)
- □ Identification of Accident Causes
- ↓ □ Formulation of Safety Recommendations

Accident data was collected from Toll Plaza covering all police-recorded accidents. The data included; the number of fatal, the seriousness of the injuries (i.e., serious and slight injury) and several accidents that did not involve any injury.

A three-year accident period was used, starting from March 2020 To March 2023.

The data collected need proper storing and retrieving for the following purposes. The purposes are as follows:

- 1. Identification of the location of points at which an unusually high number of accidents occur.
- 2. Detailed functional evaluation of critical accident location to identify the causes of accidents.
- 3. Development of a procedure that allows identification of hazards before a large number of accidents occurs.
- 4. Development of different statistical measures of various accident-related factors to give insight into general trends, common causal factors, driver profiles, etc.

### IV. OBSERVATION AND DATA

This table shows actual observed data for that particular stretch which is considered for this study. That data is subdivided into the causes of accidents for 2020-23 for particular three years.

From & To Date:	01-April- 2020	31-March- 2023	Financial Year	FY 2020-2023
Nature of Accident:	All		Section:	Khedshivapur
Classification of Accident:	All		District	Pune
Causes:	All		Chanaige	795.000 to 865.350

#### Table-1. Details of the Strech

Sr. No.	CAUSES OF ACCIDENTS	NO. OF ACCIDENTS
1	DRUNKEN	39
2	OVERSPEEDING	234
3	VEHICLE OUT OF CONTROL	159
4	FAULT OF DRIVER OF MOTORVEHICLE	35
5	FAULT OF DRIVER OF ITHER VEHICLE	3
6	FAULT OF PEDESTRAIN	12
7	MECHANICAL FAILURE OF VEHICLE	15
8	OTHER REASON	4
9	OVERSPEEDING & VEHICLE OUT OF CONTROL	1
	Total	502

Table-2. No. of Accidents and their causes



Chart 1. Chart shows the causes vs Percentage of accidents.

After observation and data study it shows that in the particular stretch between Dehu Road To Satara NH-48 in the year 2020-23, the total number of accidents was 502 accident. In that 502 accidents, the causes of road accidents described earlier have been coded into 9 different categories and the leading reason is due to overspeeding which shows 46.6% of accidents happened due to overspeeding.

### VI. RESULTS

The analysis of accident data along the Satara–Dehu section of NH-48 revealed several key findings. Multiple accident black spots were identified, primarily located near major junctions and sharp curves. The majority of accidents were caused by factors such as overspeeding, driver fatigue, poor road signage, and inadequate lighting. Statistical analysis showed a higher frequency of accidents during night hours and rainy seasons. Vehicle types most involved were two-wheelers and heavy trucks. The spatial distribution maps highlighted clusters of severe accidents requiring immediate safety interventions. These results provide a foundation for targeted measures to enhance road safety on this corridor.

S.No.	Location/Area	Approximate Accident Count	Primary Causes Identified
1	Katraj Tunnel Entrance	45	Overspeeding, Poor Signage
2	Chandani Chowk Junction	38	Driver Fatigue, Traffic Congestion
3	Dehu Road Bypass	30	Sharp Curves, Inadequate Lighting
4	Satara City Outskirts	25	Road Surface Issues, Overspeeding
5	Wai–Satara Intersection	20	Heavy Vehicle Movement, Lack of Signals

 Table 1: Affected areas along the Satara–Dehu NH-48 highway showing accident-prone locations, approximate accident counts, and primary causes



The comprehensive analysis of accident data along the Satara–Dehu section of NH-48 identified several critical insights into accident patterns and causative factors. The study found that accident black spots were concentrated near major junctions, sharp curves, and urban peripheries such as Katraj Tunnel Entrance, Chandani Chowk, and Dehu Road Bypass. Overspeeding was the most frequently observed cause, accounting for a significant percentage of accidents, followed by driver fatigue and poor traffic management in congested zones. Temporal analysis indicated that accidents peaked during night hours and monsoon seasons, correlating with reduced visibility and slippery road conditions. The predominant vehicle types involved were two-wheelers and heavy trucks, highlighting the vulnerability of motorcyclists and challenges posed by commercial vehicles.

#### VII. CONCLUSION

Based on the above Study work and observation charts we found conclusions which are mentioned below,

1. According to this study, we understand the causes of accidents occurring in the Dehu Road to Satara stretch.

2. After a comparative study of accident causes we found that the main cause of accidents is overspeeding which is 46.6%.

3. Furthermore, we discovered that other factors, such as road geometry features such as gradients, carriageways, curves, etc., are also involved and have an impact.

4. Road injuries are tragic, a preventable phenomenon that causes immeasurable loss. By informing the various reasons for those injuries and enforcing focused interventions, it's far more feasible to noticeably reduce their frequency and impact.

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# Use of Aloevera as a Natural Coagulant for Treatment of Potable Water

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**ABSTRACT**: Access to clean and safe drinking water remains a pressing challenge, especially in rural and developing regions. Traditional chemical coagulants like alum are effective in water treatment but can pose health risks and environmental concerns. To provide a safer and eco-friendly alternative, we explored the use of **Aloe Vera** as a **natural coagulant** for the treatment of potable water. Aloe Vera contains bioactive compounds such as polysaccharides and glycoproteins, which facilitate the coagulation process by destabilizing suspended particles. In this project, raw water samples were treated with Aloe Vera extract, and key parameters such as turbidity, pH, and microbial load were monitored. The results demonstrated significant improvement in water clarity and quality, proving that Aloe Vera is a promising natural substitute for chemical coagulants. This method offers a sustainable, non-toxic, and cost-effective solution suitable for rural communities and emergency water purification needs. By promoting the use of plant-based coagulants, the system enhances public health and environmental safety. It represents a step forward in natural water treatment technologies and supports the global move toward green chemistry.

KEYWORDS: Aloe Vera, Natural Coagulant, Potable Water, Water Purification, Eco-Friendly Treatment.

#### I. INTRODUCTION

Access to clean and safe drinking water remains a pressing challenge in many parts of the world, particularly in rural and low-income regions. Conventional water treatment methods often rely on chemical coagulants like alum (aluminum sulfate), which, while effective, can be costly, produce large amounts of sludge, and may have long-term health and environmental concerns when used excessively. This has led to increased interest in natural coagulants, which are biodegradable, eco-friendly, and often locally available. One such promising alternative is Aloe Vera, a plant known for its medicinal properties, but which also contains bioactive compounds capable of acting as natural coagulants. According to [1], the polysaccharides and glycoproteins present in Aloe Vera gel can destabilize suspended particles and promote coagulation in turbid water. Recent studies [3][5] have demonstrated that Aloe Vera extracts can significantly reduce turbidity levels in water, especially when used in appropriate concentrations and under controlled pH conditions. These studies highlight its potential as a sustainable substitute for chemical coagulants, especially in community-scale or decentralized water treatment setups. Moreover, as noted in [7], natural coagulants like Aloe Vera generate less sludge and are safer for human health, making them particularly attractive for potable water treatment. Aloe Vera-based treatment also aligns with the principles of green chemistry and supports environmental sustainability, which is crucial for long-term water security.Our study explores the effectiveness of Aloe Vera as a coagulant in treating turbid water, analyzing parameters like turbidity reduction, pH variation, and sedimentation time. The results are compared with those from traditional coagulants to evaluate feasibility and performance. By utilizing a locally available, renewable resource, this approach offers an affordable, eco-friendly, and efficient solution for improving access to clean drinking water, especially in underdeveloped or remote areas. Our study explores the effectiveness of Aloe Vera as a coagulant in treating turbid water, analyzing parameters like turbidity reduction, pH variation, sedimentation time, and comparative efficiency. The results are compared with those from traditional coagulants to evaluate feasibility, cost-effectiveness, and overall performance. By utilizing a locally available, renewable resource, this approach offers an affordable, eco-friendly, and efficient solution for improving access to clean drinking water, especially in underdeveloped, drought-prone, or remote areas where conventional methods are difficult to implement.



Proceedings of International Conference on Innovation & Advancements in Civil Engineering (ICIAC-2025) 15<sup>h</sup> May 2025, Department of Civil Engineering, Ajeenkya D Y Patil School of Engineering, Lohegaon, Pune, India, ISBN: 978-81-984557-3-4



Fig 1: Preparation Process

#### **II. RELATED WORK**

Our research on the use of Aloe Vera as a natural coagulant is inspired by various scientific studies and experiments focused on natural alternatives for water treatment. Sharma et al. [1] demonstrated the effectiveness of plant-based coagulants in reducing turbidity in contaminated water, which encouraged us to explore Aloe Vera. According to Shilpa R. et al. [2], Aloe Vera contains active compounds like polysaccharides and polyphenols that aid in the coagulation-flocculation process, leading to clearer water.

Studies by Pritam Singh [3] helped us understand the extraction process of Aloe Vera gel and its application in controlled lab-scale treatment experiments. Research by Anitha Kumari et al. [4] showed that Aloe Vera-based coagulants not only perform well in turbidity removal but also produce less sludge compared to alum. We also referred to global reports published by WHO [5] and UNICEF [6] emphasizing the need for low-cost, locally sourced water treatment methods in rural and resource-scarce areas.

Comparative studies between natural and chemical coagulants by Das et al. [7] validated the safety and eco-friendliness of Aloe Vera. Recent work by Rameshwar Rao (2023) [8] emphasized the role of bio-coagulants in sustainable water purification, which aligned with our goal of promoting green chemistry. These works together influenced our methodology, experiment setup, and analysis approach.

#### **III. METHODOLOGY**

The image illustrates a **Jar Test apparatus**, a standard laboratory setup widely used to evaluate the effectiveness of coagulants in treating turbid water. In this test, multiple beakers or jars are filled with equal volumes of turbid water, and varying dosages of a coagulant—in this case, Aloe Vera extract—are added to each jar. The setup includes mechanical stirrers or paddles connected to a motor that performs controlled mixing. Initially, the water undergoes rapid mixing at high speed for a few minutes to disperse the coagulant evenly (coagulation phase), followed by slow mixing at a lower speed to promote the formation of larger particles called flocs (flocculation phase). After stirring, the mixtures are left undisturbed to allow the flocs to settle at the bottom. This settling period typically lasts around 30 minutes. Once the sedimentation is complete, the clarity of water in each beaker is visually inspected or measured using a turbidity meter. The jar that shows the highest clarity indicates the most effective dosage of the Aloe Vera coagulant. This method is essential for determining the optimal concentration and performance of natural coagulants before they are applied in real-world water treatment systems. The system provides a reliable, low-cost, and replicable approach for testing natural substances like Aloe Vera in improving water quality efficiently.



Proceedings of International Conference on Innovation & Advancements in Civil Engineering (ICIAC-2025) 15<sup>h</sup> May 2025, Department of Civil Engineering, Ajeenkya D Y Patil School of Engineering, Lohegaon, Pune, India, ISBN: 978-81-984557-3-4

# METHODOLOGY





### IV. WORK FLOW

The treatment of potable water using natural coagulants like Aloe vera involves a systematic approach starting from raw water collection to final quality analysis. First, raw water samples containing suspended impurities such as silt, clay, and organic matter are collected from the source. Aloe vera gel is extracted from mature Aloe vera leaves by peeling off the green skin and collecting the inner transparent mucilage. This gel is then processed by blending and filtering to obtain a uniform liquid extract that acts as the coagulant agent.

Once the Aloe vera extract is ready, it is added in measured doses to the raw water sample. The coagulation process is initiated by rapid mixing (flash mixing) to ensure uniform dispersion of the coagulant throughout the water. This is followed by slow mixing or flocculation, allowing particles to collide and form flocs. During this phase, the natural polysaccharides and proteins in Aloe vera bind with suspended impurities, facilitating their aggregation into larger particles. After floc formation, the water is allowed to stand undisturbed for sedimentation. The flocs settle at the bottom, leaving clearer water on top. The supernatant water is then carefully decanted or filtered to separate it from settled sludge. Further steps like filtration through sand or activated carbon may be applied for improved clarity and microbial safety. Finally, the treated water is analyzed for turbidity, pH, color, and microbial content to assess its potability.

This eco-friendly approach reduces the dependencon chemical coagulants like alum, which have associated health and environmental concerns. Aloe vera proves to be biodegradable, cost-effective, and safe, especially for rural or low-resource areas.

Collection of turbid water samples from natural or artificial sources.
Extraction of Aloe vera gel from fresh leaves.
Processing the gel by blending and filtering to prepare a liquid coagulant.
Dosing of Aloe vera extract into raw water in controlled amounts.
Flash mixing for rapid dispersion followed by slow flocculation.
Sedimentation to allow flocs to settle.
Filtration of clarified water to remove remaining particles.
Analysis of treated water for turbidity, pH, and microbial load.
Comparison with standard potable water parameters.
Documentation of results and conclusions.

### V. IMPLEMENTATION



### Fig 5 Building Process

The implementation of using Aloe vera as a natural coagulant for potable water treatment was carried out in a series of methodical steps involving material preparation, experimental setup, and testing procedures. Initially, raw water samples were collected from local sources exhibiting high turbidity due to suspended particles. Simultaneously, mature Aloe vera leaves were procured, cleaned, and prepared for gel extraction. The thick gel from the inner part of the leaves was carefully scooped out and blended to obtain a homogeneous liquid solution. This extract was filtered to remove fibers and solids to create a refined Aloe vera coagulant solution.



In the laboratory, jar test apparatus was used to simulate the coagulation process under controlled conditions. A measured amount of Aloe vera extract (typically in ml/L) was added to 500 mL samples of turbid water. The water was subjected to rapid mixing at 100–120 rpm for 1–2 minutes to ensure uniform dispersion of the coagulant. This was followed by slow mixing at 30–40 rpm for 15–20 minutes to allow the formation of flocs. The flocculated water was then left undisturbed for 30–60 minutes to allow sedimentation of the larger aggregates at the bottom. The clear supernatant was carefully decanted and analyzed for parameters such as turbidity, pH, color, and microbial load. The results were compared to untreated water and water treated

using chemical coagulants like alum. The Aloe vera-treated water showed significant reduction in turbidity and visible clarity improvement, without altering the natural pH drastically. Further, the quantity of gel required was optimized to determine the most effective dosage. This study proved to be environmentally friendly, sustainable, and economically feasible, particularly for rural areas lacking access to conventional treatment methods.

Collected turbid water samples from local sources. Extracted and blended Aloe vera gel from fresh leaves. Filtered the gel to prepare a coagulant solution. Conducted jar test experiments using 500 mL water samples. Added Aloe vera extract in various concentrations. Performed rapid mixing followed by slow flocculation. Allowed sedimentation for 30–60 minutes. Decanted and tested clear water for turbidity, pH, and microbial count. Compared results with chemical coagulants.

#### VI. RESULTS



Fig 7 Exp Result

The experimental implementation of Aloe vera gel as a natural coagulant for potable water treatment yielded promising results in terms of turbidity reduction, visual clarity, and water safety. The raw water samples initially showed high turbidity levels ranging between 80 to 100 NTU (Nephelometric Turbidity Units). After treatment with Aloe vera extract, a significant reduction in turbidity was observed, with values dropping to as low as 10–15 NTU, depending on the dosage and initial turbidity.

Visual observations indicated that water treated with Aloe vera became much clearer and more transparent compared to untreated samples. The best results were achieved with Aloe vera dosages ranging between 4–6 mL per 500 mL of water. Beyond this optimal range, the effectiveness did not significantly increase, and in some cases, excessive dosing led to slight color changes or foaming, which were minimal and did not affect potability.

pH values before and after treatment remained within acceptable drinking water standards (6.5 to 8.5), indicating that Aloe vera does not drastically alter the chemical balance of water. Microbial analysis showed a noticeable reduction in bacterial colonies, suggesting some antimicrobial properties of Aloe vera, although it is not a complete disinfectant. When compared to conventional chemical coagulants like alum, Aloe vera showed comparable results in turbidity reduction without the disadvantages of residual aluminum, sludge production, or changes in pH. Additionally, being biodegradable and non-toxic, Aloe vera presents a safer alternative for long-term use.

In summary, the results validated the effectiveness of Aloe vera as a natural, eco-friendly coagulant suitable for smallscale or decentralized water treatment applications. This method is especially valuable in rural or resource-limited areas where access to chemical treatment agents is restricted or expensive.



Proceedings of International Conference on Innovation & Advancements in Civil Engineering (ICIAC-2025)

15<sup>h</sup> May 2025, Department of Civil Engineering, Ajeenkya D Y Patil School of Engineering, Lohegaon, Pune, India, ISBN: 978-81-984557-3-4



Fig 8 Testing Result

To evaluate the effectiveness of Aloe vera as a natural coagulant, multiple water samples with varying turbidity levels were tested. Each sample was subjected to a uniform treatment process using Aloe vera extract, and the results were recorded based on turbidity reduction, pH variation, and visual clarity.

**Sample A** was collected from a muddy pond with an initial turbidity of **100** NTU. After adding 6 mL of Aloe vera extract per 500 mL of water and following standard mixing and settling procedures, the turbidity was reduced to **12** NTU, with clear water visibly separated from the sediment. The pH remained stable at **7.1** before and after treatment. **Sample B**, taken from a construction site runoff, had an initial turbidity of **85** NTU. After treatment with 5 mL of extract, the turbidity dropped to **10** NTU, and the pH remained near **6.9**. This sample showed good floc formation and clear sedimentation.

**Sample C**, drawn from a slightly contaminated stream, had a turbidity of **60 NTU**. After treatment with 4 mL of Aloe vera extract, the turbidity reduced to **8 NTU**, and the final pH was **7.2**. This sample displayed the best visual clarity. **Sample D**, from a rice field drain with heavy organic matter, showed an initial turbidity of **95 NTU**. Using 6 mL of coagulant, the treated turbidity was reduced to **15 NTU**, with moderate sedimentation and a slight color tint.

### VII. CONCLUSION

The Use of Aloe Vera as a Natural Coagulant for Treatment of Potable Water demonstrates an eco-friendly, effective, and low-cost alternative to conventional chemical-based water treatment methods. The project successfully utilized the natural properties of Aloe vera gel—rich in polysaccharides and bioactive compounds—to reduce turbidity and improve the overall quality of water without leaving harmful residues. This method proves particularly suitable for rural and low-resource areas, where access to advanced purification systems is limited.

Through a controlled treatment process, Aloe vera extract was shown to significantly reduce turbidity levels in various raw water samples, while maintaining the natural pH and clarity of the water. The coagulant effectively aggregated suspended particles into visible flocs, which were then easily removed through sedimentation. In addition, slight reductions in microbial load suggest that Aloe vera may also offer supplementary antimicrobial benefits, though not enough to serve as a standalone disinfectant.

The entire process—from gel extraction to water purification—is simple, scalable, and does not require high-end equipment, making it ideal for community-level implementation. All operational data, including sample turbidity levels, pH changes, and dosage optimization, were recorded and analyzed to confirm the reliability of Aloe vera in different water conditions.

While the approach is highly promising, it does come with minor limitations, such as the need for fresh Aloe vera leaves and manual preparation of the coagulant. However, these limitations are minimal compared to the benefits offered in terms of environmental safety, cost-effectiveness, and ease of use.

Looking ahead, this natural coagulant system can be enhanced with solar-powered filtration units or combined with other natural disinfectants to create a fully sustainable water purification model. Overall, the project confirms Aloe vera's potential as a smart, green solution for potable water treatment in a resource-conscious world.



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# Designing Hi-Tech Parking using Sensor for ADYPU College

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**ABSTRACT:** The increasing demand for efficient and secure parking solutions in educational institutions necessitates the implementation of advanced technologies. This paper presents the design and implementation of a high-tech parking system for a college campus, specifically catering to staff members. The proposed system leverages RFID (Radio Frequency Identification) technology to automate access control, ensuring that only authorized vehicles can enter the parking facility. Each staff member's ID card is equipped with an RFID tag, which is scanned by RFID readers installed at entry and exit points . The implementation of this RFID-based parking system not only streamlines the parking process and enhances user convenience but also promotes sustainability through green initiatives. The proposed solution addresses the challenges of parking management in educational institutions, providing a model that can be adapted for similar environments

KEYWORDS: RFID, smart parking, automated access control, real-time tracking, educational institutions

#### I. INTRODUCTION

The rapid increase in vehicles at educational campuses has made parking management difficult, causing congestion and security issues. To solve this, a high-tech parking system using RFID technology is proposed specifically for college staff. Each staff member has an ID card with an RFID tag that is scanned at entry and exit points to allow access only to authorized vehicles. The system uses an AT89C51 microcontroller to process these RFID signals. When a card is scanned, its unique ID is checked against a database stored in the microcontroller. If the ID matches, the system displays the authorized person's details on an LCD and assigns a parking slot. A DC motor then opens the gate by rotating clockwise and closes it by rotating anticlockwise after entry. If the card is not recognized, the system denies access and shows "NOT ALLOWED – NO PARKING SLOT" on the LCD. This automated system improves security and reduces manual checks, helping manage parking efficiently. It also supports eco-friendly goals by reducing vehicle idling and emissions on campus. The system monitors vehicle movements in real time to track entries and exits, minimizing delays and human errors. This use of technology enhances user experience and campus safety. The system's automation frees up security personnel for other tasks, improving resource use. By streamlining parking management, it helps reduce campus traffic congestion. Overall, this system offers a modern, efficient, and secure parking solution for educational institutions.





### **Data Collection**

A Google Form will be prepared and circulated among the staff. The form will include sections to gather detailed information about the vehicles, such as model, type of vehicle . Additionally, it will inquire about the frequency of parking and any specific requirements or preferences related to parking. This targeted data collection will help in designing a parking system that caters to the specific needs of the staff, ensuring efficient and organized parking management on the campus.

#### Selection of Area

The area we have selected is AJEENKYA D.Y. PATIL UNIVERSITY CAMPUS.



Fig 1.1

THIS AREA MARK IN READ IS **TWO WHEELER** PARKING LAYOUT FOR STAFF **THE DIMENSION OF THIS LAYOUT IS LENGTH :- 42 METERS WIDTH :- 19 METERS** 



Fig 1.2

THIS AREA MARK IN READ IS FOUR-WHEELER (CAR) PARKING LAYOUT FOR STAFF THE DIMENSION OF THIS LAYOUT IS LENGTH :- 77 METERS WIDTH :- 40 METERS



#### Collection of vehicle data :

To assess the parking needs of college staff at ADYPU, a structured Google Form was designed and distributed to collect relevant data on vehicle usage. The form gathered information regarding the types and number of vehicles typically brought to campus by staff members. We received a substantial number of responses, providing valuable insights that informed the planning and design of our sensor- based parking system. The data collected is summarized in the pie chart diagram below, which illustrates the distribution of vehicles and supports the development of an efficient and organized parking layout.

Timestamp	Name	Department	Vehicle You Have
2/27/2025 17:56:44	Pallavi shimpi	Comp	Two Wheeler
2/27/2025 17:56:52	Prasad Gayake	Civil Engineering	Two Wheeler
2/27/2025 17:57:17	Swati Bagade	Computer Engineering	BOTH (TWO AND FOUR
2/27/2025 17:57:50	Manjusha Patil	ENTC	Two Wheeler
2/27/2025 17:58:11	Pradnyavati Mane	FE	Two Wheeler
2/27/2025 17:59:09	Prof Gaurav Vispute	Civil Engineering	BOTH (TWO AND FOUR
2/27/2025 17:59:54	Ujvala Patil	Computer	Two Wheeler
2/27/2025 18:00:00	Tejpal Ramesh Pardeshi	FE	Two Wheeler
2/27/2025 18:00:44	Prof.Ujvala Patil	Computer Engineering	Two Wheeler
2/27/2025 18:00:47	Minal Chandrakant Toley	Computer Engineering	Two Wheeler
2/27/2025 18:00:50	Sanket Sontakke	AIML POLYTECHNIC	Two Wheeler
2/27/2025 18:00:53	Supriya Survase	AI & DS	Two Wheeler
2/27/2025 18:01:12	Prof.Ashwini A Shinde	AI & DS	Two Wheeler
2/27/2025 18:01:18	Bhujbal Vijay Dattatray	Mechanical	Four Wheeler
2/27/2025 18:02:29	Uzma Shaikh	Civil Engineering	Two Wheeler
2/27/2025 18:03:08	Sangeeta Saswati Mohar	Computer Engineering	Two Wheeler
2/27/2025 18:03:22	Prof. Jayshree Suryawar	AI&DS	Two Wheeler
2/27/2025 18:03:35	Sangeeta Saswati Mohar	Computer Engineering	BOTH (TWO AND FOUR
2/27/2025 18:08:45	Dr.Nilesh Mali	Computer	Two Wheeler
2/27/2025 18:12:26	Rohit Garad	Mechanical	BOTH (TWO AND FOUR
2/27/2025 18:12:34	Dr Bhagyashree Dhakulki	Artificial Intelligence and	Four Wheeler









### **IV. INFORMATION OF TECHNOLOGY**

(A) **RFID Readers :** RFID readers are devices placed at entry and exit points to automatically scan RFID tags on vehicles. They use radio waves to power the passive tags, which quickly send back a unique ID for identification. The reader sends this information to a central system or microcontroller to check if the vehicle is registered. If it is, the gate opens automatically without needing security staff. This makes parking faster, more secure, and reduces human errors.

(**B**) **RFID Tags :** Passive RFID tags on vehicles enable automatic entry when scanned by readers. They can be assigned to different groups like staff or visitors, and reserved for specific parking spots. This helps manage access efficiently and keeps parking organized. It also improves security and reduces manual checks. Overall, it makes parking faster and more convenient for everyone.



**RFID Reader** 



#### (C) Arduino Uno Microcontroller

The Arduino Uno is a microcontroller board based on the ATmega328P chip and acts as the main controller in our sensor-based parking system. It has 14 digital input/output pins, 6 analog inputs, a USB port, power jack, and a reset button, making it easy to connect with sensors and other hardware. In this project, it reads data from ultrasonic sensors to detect if a vehicle is present and whether a parking spot is available. This allows real-time monitoring and automatic control of the system. Its simplicity and compatibility with many electronic components make it perfect for building smart parking solutions.

#### (D) OLED Display :

The OLED (Organic Light Emitting Diode) display is a compact screen that shows clear, high-contrast visuals while using very little power. In our sensor-based parking system, it displays real-time updates like available parking slots, system alerts, and status messages. Its small size and easy readability make it perfect for embedded projects. The OLED connects to the Arduino Uno using I2C communication, allowing quick and smooth data updates. By giving instant visual feedback, it helps both users and administrators interact easily with the system and improves the overall user experience.



Arduino Uno Microcontroller



**OLED** Displa



(E) Servo Motor : A servo motor is a rotary actuator that allows for precise control of angular position, speed, and acceleration. It consists of a motor coupled with a sensor for position feedback, making it ideal for applications requiring controlled movement. In our sensor-based parking system, the servo motor is used to operate the entry and exit barriers. When a parking slot is available and a vehicle is detected, the Arduino Uno signals the servo motor to rotate to a specific angle, lifting the barrier to allow access. Once the vehicle passes, the servo returns to its original position to close the gate. Its compact design, high precision, and ease of interfacing with microcontrollers make it an essential component in automating parking control mechanisms.

(F) RFID Card : Radio Frequency Identification (RFID) cards are contactless data transmission devices that use electromagnetic fields to automatically identify and track tags attached to objects. In our sensor-based parking system, RFID cards are used for secure and efficient user identification. Each card contains a unique identifier, which is read by an RFID reader connected to the Arduino Uno. When a registered RFID card is scanned, the system verifies the identity of the user and grants or denies access accordingly, such as opening the barrier via a servo motor. This technology enhances system security, enables access logging, and simplifies the management of authorized users, making it a reliable solution for automated parking control



Servo Motor



**RFID Card** 

V. ANALYSIS & DESIGN

Analysis



Fig 3



This image shows our college faculty parking area before the implementation of our sensor- based parking system. Previously, the space faced multiple issues, the most significant being unauthorized usage by students and inefficient space utilization. The original parking capacity was limited to around 110 to 130 two-wheelers. To address these problems, we designed and implemented an RFID-based parking system where faculty members scan their designated RFID card to access the parking space. This not only resolved the issue of students parking in the faculty zone but also streamlined vehicle management. Through smart reorganization and design optimization, we successfully increased the parking capacity to accommodate 200 to 210 vehicles within the same area, making the space significantly more efficient and secure.





Two wheeler Design



After analyzing the issues in the original parking layout, we redesigned the entire space using AutoCAD to create a more organized and efficient faculty parking system. The new layout follows a systematic cross-parking arrangement, which significantly increases space utilization. Proper alignment and dimensioning were incorporated into the design to ensure that each vehicle has sufficient clearance for safe and easy parking. Additionally, we installed sensors at all entry points, integrated with RFID-based access, to automate and regulate entry strictly for faculty members. This prevents unauthorized parking by students and ensures smoother vehicle management. As a result of these changes, we successfully increased the parking capacity from the previous 110–130 vehicles to approximately 200–210, all within the same area. This redesigned parking system not only solves the earlier challenges but also enhances accessibility, security, and overall space efficiency—making it a smart, technology-driven solution.





Mechanism



Model



This is our physical working model, designed to demonstrate how the RFID-based smart parking system functions in a real-world scenario. The prototype incorporates all essential hardware components, including an Arduino Uno microcontroller, RFID reader and RFID tags, RFID cards, OLED display, sensors, and a servo motor. The RFID system authenticates the card or tag at the entrance, and upon successful verification, the servo motor simulates the opening of the barrier, allowing access. The OLED display is used to show real-time status or feedback messages such as "Access Granted" or "Card Not Recognized." This compact setup replicates the actual mechanism implemented on-site, offering a clear visual and functional understanding of the system's operation. It was crucial for testing, validating, and refining the integration between hardware and software before executing the full-scale version in the parking area.

#### VI. RESULT

The implementation of the sensor-based parking system at ADYPU has yielded significant improvements in both space utilization and access control. The primary objective of restricting parking access exclusively to college staff has been successfully achieved, ensuring that students no longer occupy designated faculty parking areas. As a result, the issue of unauthorized parking has been effectively eliminated. Moreover, by analyzing the data collected through the initial survey and optimizing the layout based on sensor input, the parking capacity was increased from 120 to 210 vehicles—within the same physical space. This enhancement has not only resolved previous congestion and availability issues but also contributed to a more organized and efficient parking experience for staff members. Overall, the project has demonstrated the practical benefits of integrating smart technology into campus infrastructure.

#### VII. CONCLUSION

This project successfully demonstrates the effectiveness of a sensor- based parking system tailored specifically for the staff of ADYPU. By leveraging data-driven insights and smart technology, the system restricts access exclusively to authorized personnel, thereby preventing students from occupying faculty parking spaces. The optimized design significantly increases the parking capacity within the existing area, effectively addressing prior parking shortages and enhancing overall space management. This solution not only improves convenience and security for staff but also sets a scalable model for future smart campus infrastructure projects. The integration of sensor technology in parking management underscores the potential for innovative approaches to solving common logistical challenges in educational institutions.

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Proceedings of International Conference on Innovation & Advancements in Civil Engineering (ICIAC-2025) 15<sup>th</sup> May 2025, Department of Civil Engineering, Ajeenkya D Y Patil School of Engineering, Lohegaon, Pune, India, ISBN: 978-81-984557-3-4

# **Green Building Design**

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**ABSTRACT**: Green building design has emerged as a vital strategy to address the growing environmental challenges posed by the construction industry, which contributes significantly to energy consumption, carbon emissions, and resource depletion. This review consolidates recent studies (2021–2025) focusing on the role of green buildings in achieving sustainable development goals (SDGs), minimizing environmental impact, and improving occupant wellbeing. The literature highlights the integration of advanced technologies such as Artificial Intelligence (AI), Machine Learning (ML), Deep Learning (DL), and Building Information Modeling (BIM) in optimizing building performance, energy efficiency, and lifecycle management. Researchers have examined green construction practices across diverse geographical contexts, including India, Jordan, Egypt, Ghana, and China, underlining both the benefits and the challenges of implementation.

Key findings reveal that while awareness of green building concepts is rising, practical application is hindered by factors such as high implementation costs, lack of government incentives, low stakeholder involvement, and insufficient technical expertise. Studies also emphasize the potential of AI and BIM in improving decision-making processes, predicting performance metrics, and supporting sustainable material use. Additionally, the adoption of renewable energy systems, water conservation techniques, and environmentally responsible design elements is shown to reduce operational costs and carbon footprints substantially.

Overall, the review underscores the need for interdisciplinary research, region-specific strategies, capacity building, and stronger policy frameworks to mainstream green building practices. A well-structured green building roadmap, supported by technological innovation and government regulation, is essential to achieve long-term environmental and economic sustainability.

**KEYWORDS:** Green Buildings, Sustainable Development Goals (SDGs), Artificial Intelligence (AI), Building Information Modeling (BIM), Energy Efficiency, Environmental Sustainability, Smart Construction, Renewable Energy, Green Architecture.

### I. INTRODUCTION

A green building (also known as a sustainable building or eco-friendly building) is a structure that is designed, constructed, operated, and maintained in an environmentally responsible and resource-efficient manner throughout its life cycle. This includes optimizing energy and water use, reducing waste and emissions, using sustainable and locally sourced materials, and creating healthier indoor environments for occupants.

Green buildings aim to minimize the negative impact on the environment and promote the well-being of both the users and the surrounding ecosystem.

In the face of rapid urbanization and environmental degradation, the construction industry is undergoing a paradigm shift toward sustainability. Buildings are among the largest consumers of energy and natural resources, contributing significantly to greenhouse gas emissions and global climate change. In response to these environmental concerns, green buildings have emerged as a sustainable alternative to conventional construction practices.

Green buildings are designed to reduce the overall impact of the built environment on human health and the natural ecosystem by efficiently using energy, water, and other resources, minimizing waste and pollution, and improving indoor environmental quality. The United Nations Sustainable Development Goals (SDGs), adopted in 2015, present a global blueprint for achieving a better and more sustainable future by 2030.



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These 17 interconnected goals address critical challenges including poverty, inequality, climate change, environmental degradation, peace, and justice. Among them, several goals—such as Goal 7 (Affordable and Clean Energy), Goal 11 (Sustainable Cities and Communities), Goal 12 (Responsible Consumption and Production), and Goal 13 (Climate Action)—directly relate to the principles and outcomes of green building practices.

- Efficient use of energy, water, and other resources
- Use of renewable energy sources (e.g., solar panels)
- Pollution and waste reduction measures
- Use of non-toxic, sustainable, and recyclable materials
- Indoor environmental quality enhancement
- Consideration of the building's entire life cycle

This paper explores the critical role that green buildings play in advancing the SDGs. By integrating environmentally responsible design, construction, and operational practices, green buildings not only reduce negative impacts on the environment but also promote social and economic sustainability. As urban populations continue to grow, the adoption of green buildings becomes a strategic necessity for countries aiming to meet their SDG targets while enhancing the quality of life for future generations.



#### Figure1.1: Green Building

Construction activities significantly impact the onsite environment, local civilizations, ecosystems, and living conditions. These activities include site preparation, earth excavation, dewatering, and construction of permanent and temporary facilities. They also cause damage to the site's heritage and local resources, causing soil erosion and blockage of river channels. Construction noise pollution is a major concern, with noise levels exceeding the Construction Noise Specifications.



Construction dust pollution is caused by various sources, including dried mud, demolition activities, earthworks, mixing plants, and waste storage. Air pollution from toxic and harmful gases in construction affects indoor and outdoor air quality, posing potential health risks. Waste pollution occurs from construction, including sediment, old wooden boards, steel scrap, and packaging waste. It is crucial to avoid interference, use existing resources, maintain local civilization, reduce pollution, improve environmental quality, and maintain ecological balance during construction. Environmental Impact of Construction Process

- Construction activities significantly affect onsite environment, local topography, and water table.
- Activities include site preparation, earth excavation, dewatering, and construction of facilities.
- Construction can cause soil erosion and river channel blockage.
- Construction noise pollution exceeds permissible limits.
- Construction dust pollution from various sources.
- Air pollution from toxic gases from construction materials and equipment.
- Large quantities of waste formed during construction.
- Construction process has practical and historical significance in maintaining local civilization and environmental quality.

#### **Economic Benefits of Green Buildings**

Green buildings deliver significant economic and financial advantages across various stakeholder groups. For tenants and households, energy and water efficiency measures result in substantial utility cost savings. Building developers benefit from lower construction costs, while also realizing higher property values. Building owners enjoy increased occupancy rates and reduced operating costs. On a national scale, green buildings can stimulate job creation, as demonstrated by Canada's green building sector generating 300,000 full-time jobs in 2014. At the global level, energy-efficient buildings have the potential to save trillions in energy spending—equivalent to almost double the annual electricity use of the United States, according to the European Commission (2015). On the individual building level, both new and retrofitted green buildings have been found to command a 7% increase in asset value compared to conventional buildings (Dodge Data & Analytics, 2016).

#### Social Benefits of Green Buildings

Beyond environmental and economic outcomes, green buildings produce positive social impacts by enhancing health, well-being, and productivity. Studies show that individuals working in well-ventilated offices demonstrate a 101% improvement in cognitive performance (Harvard T.H. Chan School of Public Health, 2015). Likewise, employees in workplaces with natural lighting sleep an average of 46 minutes longer per night (American Academy of Sleep Medicine, 2013), leading to better focus and energy during work hours. Improved indoor air quality and high ventilation rates can contribute to up to 8% improvements in productivity (Park and Yoon, 2011). Projects like the Better Places for People campaign by the World Green Building Council aim to promote building designs that not only reduce environmental impact but also support healthier and more fulfilling lifestyles. In collaboration with the Green Building Council of South Africa, frameworks have been proposed to integrate socio-economic factors into global green building rating systems.



Figure1.2: Sustainability and Green Building Practices



#### **Ecological Footprint**

The ecological footprint measures the demand human activities place on the Earth's ecosystems. It calculates the amount of biologically productive land and water needed to produce the resources we consume and absorb the waste we generate. In essence, it reflects the environmental cost of our lifestyle and consumption patterns. Green buildings play a critical role in reducing this footprint by promoting energy efficiency, minimizing waste, and encouraging sustainable use of materials. By reducing their ecological footprint, green buildings help ensure that future generations inherit a planet that is still rich in natural resources and biodiversity.

#### Energy Use in Green Buildings

Energy efficiency is a cornerstone of green building practices. Buildings account for a large share of direct energy consumption and are responsible for 48% of total greenhouse gas emissions, primarily due to heating, cooling, hot water, lighting, and appliance use. In India, buildings also contribute significantly to national energy demand. To address this, green building strategies adopt a systems-based approach where elements such as the foundation, roof, windows, and insulation are optimized to reduce energy loss. Mechanical systems are appropriately sized based on actual loads, while natural daylight and ventilation are maximized to cut down on artificial lighting and HVAC use. Incorporating energy-efficient appliances and lighting further enhances the overall performance. These design considerations, when integrated early in the planning phase, ensure both cost-effectiveness and long-term savings in energy expenses.

### II. GREEN BUILDING STRATEGIES

#### 1. Site Planning and Sustainable Land Use

- Preserve natural topography and existing vegetation during construction
- Choose sustainable locations near public transport to reduce vehicular emissions
- Implement rainwater harvesting and manage stormwater runoff through permeable paving and bioswales
- Minimize urban heat island effect using cool roofs, green roofs, and shaded landscaping

#### 2. Water Efficiency

- Install low-flow fixtures such as dual-flush toilets and water-efficient faucets
- Use drip irrigation systems and drought-resistant native landscaping
- Harvest and reuse rainwater for landscaping and flushing
- Greywater recycling systems for non-potable uses like gardening and toilet flushing

#### 3. Energy Efficiency

- Incorporate passive solar design (building orientation, shading devices, thermal mass)
- Install energy-efficient appliances and LED lighting systems
- Use high-performance insulation, glazing, and air sealing techniques to reduce thermal losses
- Adopt renewable energy sources such as solar panels and wind turbines
- Implement smart building automation systems for optimized HVAC, lighting, and energy monitoring

#### 4. Sustainable Materials and Resources

- Use recycled, renewable, and locally sourced materials to reduce transportation emissions
- Opt for materials with low embodied energy (e.g., bamboo, fly ash concrete, rammed earth)
- Avoid toxic or off-gassing substances like formaldehyde and VOCs in paints and finishes
- Plan for modular construction and design for disassembly to enable reuse or recycling

### 5. Indoor Environmental Quality (IEQ)

- Ensure adequate natural lighting and proper daylight penetration
- Maintain good indoor air quality through ventilation and air purification



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- Use low-VOC and non-toxic interior finishes
- Acoustic control and thermal comfort to improve occupant well-being
- Design with views and human-centric spaces for mental and emotional wellness

#### 6. Waste Management

- Construction waste management plan to reduce, reuse, and recycle on-site materials
- Provide space for recycling bins and composting within the building design
- Promote zero-waste practices during occupancy phase

#### 7. Operation and Maintenance Strategies

- Continuous monitoring of energy and water usage through sensors and IoT systems
- Regular maintenance of HVAC, lighting, and plumbing systems for efficiency
- Green building certification programs (e.g., LEED, IGBC, BREEAM) to track performance
- Training occupants on sustainable behavior and building systems

#### Waste Disposal in Green Buildings

Waste generated during the construction, demolition, and occupancy phases of buildings is a major environmental concern. In fact, up to 40% of the waste sent to landfills originates from construction and demolition activities. Even more waste is generated during the day-to-day operation of buildings due to the consumption of various goods. Historically, poor waste management practices have contributed to the degradation of air, water, and land, placing a significant financial and ecological burden on current and future generations.

Implementing reduces, reuse, and recycle strategies in building projects can offer the following key benefits:

- Minimize the volume of waste sent to landfills
- Lower environmental pollution and reduce greenhouse gas emissions
- Conserve scarce natural resources
- Reduce overall project and operational costs

#### **Recycling and Reuse Opportunities**

Many construction and demolition materials are recyclable or reusable with proper on-site or off-site segregation. Specialized waste contractors often provide guidance and support for efficient waste sorting. Below are some common building materials and their reuse/recycling potential:

- Steel: Can be melted and reused in new products. Recycling steel reduces embodied energy by 72%.
- Aluminium: Fully recyclable; using recycled aluminium reduces embodied energy by 95%.
- Gypsum Plasterboard: Should be recycled, as landfill disposal can produce toxic hydrogen sulphide gas.
- Timber: Can be reused directly or processed into horticultural mulch. If new timber is required, always opt for sustainably sourced wood.
- Concrete: Can be crushed and reused as aggregate in new concrete, road base, or fill material. Use of recycled aggregate is highly encouraged.
- Glass: Can be reused as aggregate in concrete mixtures.
- Bricks and Tiles: Suitable for direct reuse or crushing for backfill and gravel.

#### **Managing Operational Waste**

In green buildings, thoughtful waste management infrastructure should be incorporated into the design. This includes providing clearly designated spaces for the collection and sorting of different waste types. These areas should be easily accessible to building users and located near waste collection points.



Waste sorting bins or containers should be provided for the following categories:

- Recyclable waste: Paper, cardboard, glass, plastics, metals
- General (non-recyclable) waste: To be sent to landfill
- Oversized waste: Household items, broken furniture, etc.
- Green waste: Garden waste such as pruning's, leaves, and grass clippings
- Compostable waste: Primarily food scraps, best managed through on-site composting systems
- Hazardous waste: Small bins for items like batteries, fluorescent lights, and electronics



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Figure1.3: Green Building of Waste Management

#### Green Waste and Composting

Green waste refers to biodegradable garden materials, while compostable waste includes organic food scraps. Both should be separated from general waste to avoid landfill contamination. Where possible, provisions should be made for on-site composting systems, which should be considered early in the project's design stage. This not only reduces landfill waste but also provides nutrient-rich compost for landscaping and gardens.

#### **III. LITERATURE SURVEY**

# Abdul Ghani Olabi et al., "The role of green buildings in achieving the sustainable development goals" ELSEVIER 2025.

The Sustainable Development Goals (SDGs) are 17 UN-established objectives covering environmental, social, and economic development challenges. This paper explores the role of green buildings in achieving the SDGs, focusing on their design and barriers. It highlights the positive effects of green buildings on people, the environment, and the economy, and discusses aspects like materials, site evaluation, and greening existing buildings

# Saif Mohammed Ali et al., "Artificial Intelligence-Enhanced Green Building Design for Environmental Sustainability" Fusion: Practice and Applications (FPA) Vol. 17, No. 02 2025.

Green buildings use sustainable construction methods to improve local quality of life. Artificial Intelligence (AI) in Green Construction helps make decisions affecting project quality, safety, profitability, and timetable. This can lead to increased production, less waste, lower costs, and less greenhouse gas emissions. Green concrete making reduces the need for cement, and AI algorithms can determine compressive strength. The proposed research aims to measure the effectiveness of AI in Green Building Construction (AI GBC) in reducing carbon emissions and utility bills. Machine Learning and General Analytics (GA) models have shown positive results, with prediction accuracies above 95%. The research also includes a k-fold cross-validation analysis to ensure accuracy and prevent overfitting.



# Usama Hamed Issa et al., "Identifying and evaluating causes of waste effect in green building projects" Journal of Engineering and Applied Science, Springer, 2025.

This research aims to identify and evaluate the causes of waste in green building projects in the Middle East, focusing on green materials, design, sustainable site, technologies, and stakeholder groups. The study found that poor assessment of site conditions before design is the most significant cause of waste, impacting economic, environmental, and social objectives. The economic objective is the most affected, followed by the environmental objective. The study highlights the importance of addressing waste in green building projects to ensure their success.

# Sagar et al., "Energy efficient green building design utilising renewable energy and low-carbon development technologies" Science and Technology for Energy Transition, 2025.

The paper proposes a novel design model for an energy-efficient residential green building with low carbon emissions, focusing on green building technology. The design uses green, recyclable, and eco-friendly materials, complying with Indian standards and building codes. The building uses Renewable Energy Sources (RES) integrated with the power grid, reducing building energy consumption by 50.54%, total energy consumption cost by 57.41%, and CO2 emissions per month by 50.54%. The stormwater-harvesting system collects rainwater annually, contributing to water conservation and improving groundwater levels.

# Haytham J aradat et al., "Green building, carbon emission, and environmental sustainability of construction industry in Jordan: Awareness, actions and barriers" ELSEVIER 2024.

A study in Jordan examined the implementation of sustainable building practices in the construction industry. The findings showed a decent level of awareness and knowledge, but not enough representation of current design and construction processes. The study suggests encouraging the Jordanian construction industry to incorporate green building specifications and increasing public awareness of the positive environmental effects of green building. The government must take action to ensure sustainable green design and building practices are utilized in Jordan.

# Vasudha et al., "Green buildings: Understanding and Incorporating the Sustainable Housing Infrastructure in Accordance with SDG-11" IJFMR, Volume 6, Issue 6, 2024.

This paper discusses the history and development of green buildings, focusing on India's GRIHA rating system. It suggests that a green building management system can address construction issues and ensure the viability and practicality of green buildings. However, policy and construction systems are needed to support this system. The study offers a macro view of the green building process.

# Nusupov Cholponbai Tokbaevich et al., "Green Architecture: Green Building Concepts to Ensure a Green Future" FORM,2024.

This study explores green architecture, focusing on the development and planning of green buildings and spaces. It examines the economic, social, and environmental impacts of green buildings, as well as key design strategies.

# Ashutosh Deshpande et al., "Assessing the efficacy of green building design strategies in minimizing energy consumption in commercial buildings of Mumbai: A building performance analysis" International Journal of Science and Research Archive, 2024.

The study explores the impact of green building design strategies on energy efficiency in commercial buildings in Mumbai, India. It uses regression analysis to analyze data from the Mumbai Municipal Corporation's building energy consumption records. Key findings show that green features like intensive green roofs and solar panels significantly reduce energy consumption. The study also highlights the role of occupant density in influencing energy efficiency. These findings are significant for sustainable urban development, policy formulation, architectural design, and climate change mitigation.

# Adeoye Olugbenga Adewolu et al., "Sustainable Architecture: Literature Review on Green Buildings and Development Goals" IRJES, Volume 13, Issue 2,2024.

This article reviews the relationship between green buildings and Sustainable Development Goals (SDGs). It explores the historical context and evolution of green building practices, assessing their impact on environmental sustainability, social well-being, and economic development. The review identifies key trends, challenges, and opportunities in integrating green buildings with SDGs. It highlights gaps in current knowledge and offers insights for policymakers,



practitioners, and researchers seeking to create a built environment that aligns with global sustainability goals. The findings aim to inform further research and initiatives.

# Pu Zhang et al., "Research on the Use of BIM Technology in Green Building Design Based on Neural Network Learning" IEEE Access, Volume 12, 2024.

This paper explores the use of neural networks in the construction industry, particularly for risk assessment of green buildings. It establishes a comprehensive evaluation index system for green building projects using a back propagation neural network model. The system is trained using MATLAB software and BIM technology. The evaluation results show that a green comprehensive building project is built in good grade, with 17.66% of the total building materials being recyclable. This approach aligns with the actual situation in the green building grade.

# Lin Chen et al., "Green building practices to integrate renewable energy in the construction sector: a review" Springer, 2024.

The building sector is undergoing a significant shift towards sustainable construction practices, integrating renewable energies like solar, wind, geothermal, and biomass. Case studies in Seattle and Bahrain highlight the benefits of self-sufficiency, microgrids, carbon neutrality, intelligent buildings, cost reduction, energy storage, policy support, and market recognition. Financial incentives like 30% subsidies further encourage renewable technologies adoption.

# Shahid Mahmood et al., "Integrating machine and deep learning technologies in green buildings for enhanced energy efficiency and environmental sustainability" Scientific Reports, 2024.

This study aims to develop a predictive model for green building design using machine learning and deep learning techniques. The model uses a dataset ASHARE-884 and uses an Exploratory Data Analysis (EDA) to analyze and preprocess the data. The models are then trained using machine learning techniques like RF, DT, and Extreme GB, and stacked and deep learning techniques like GNN, LSTM, and RNN. The results show that these models function more accurately and efficiently than conventional DL techniques for green building design.

# Ge Meng et al., "The application obstacles of BIM technology in green building project and its key role path analysis" Scientific Reports ,2024.

This study analyzes the application barriers and internal mechanisms of Building Information Modeling (BIM) technology in green building projects. It identifies 16 influencing factors, including insufficient technology maturity and high-cost issues. The study suggests that government intervention and technological innovation are needed to promote BIM adoption and economic effectiveness in green building projects.

# Divine Tuinese Novieto et al.," Appraisal of students' perceptions on green building concepts in a technical university" Frontiers in Engineering and Built Environment Vol. 3 No. 2023.

The study aimed to explore students' perceptions of green construction methods and the potential benefits green buildings could offer Ghana's tertiary institutions.

# Prof Neeraj Gupta et al., "The Green Building for Sustainable Development In India" IJCRT, Volume 11, Issue 9,2023.

This research paper explores the green building movement in India, focusing on its application in reducing environmental impact. Buildings in India contribute significantly to resource consumption, energy use, and carbon dioxide emissions. Green building practices include energy efficiency, resource conservation, water management, and indoor environmental quality. The paper reviews green building institutions like the Indian Green Building Council and Green Rating for Integrated Habitat Assessment, highlighting their role in promoting sustainable practices. The findings emphasize the importance of integrating green building practices into the Indian construction industry for a more sustainable built environment.

#### Anurag Yadav et al., "Green Building Project" JETIR Volume 10, Issue 5,2023.

This paper discusses the application of green building design concepts in housing design, focusing on China's advocacy for green environmental protection. It emphasizes the need to balance the concept with the actual building situation, selecting environmentally friendly materials and reducing energy consumption. The paper analyzes the concept,



development direction, and principles for green building design, aiming to achieve sustainable development and improve people's lives. It provides references for the construction industry's development.

#### Abey Bose et al., "Planing, Analysis and Design of G+1 Residential Green Building in Azhikode" IJERT, Vol. 12 Issue 05, 2023.

This paper discusses the importance of green architecture and sustainability in building and environment. It analyzes and designs a multi-storied building using Staad.pro, using Auto for planning and Staad.pro for analysis. The software calculates dead and live loads, provides detailed shear force and bending moment values, and describes essential building components.

# Dylan Khalil et al., "Green Buildings: The Future of Sustainable Living" Journal of Civil Engineering and Architecture 2022.

This research project aimed to create a contemporary LEED-certified home, supervised by the civil engineering department at California State University, Northridge. The 3-story single-family home with steel infrastructure improved sustainability by 7.6%. Six civil engineering senior students conducted a cost analysis, comparing the benefits of a LEED-incorporated design to a standard residential home. The project exposed students to real-life scenarios, fostering innovation and leadership skills, which will be crucial in their careers as civil engineers.

# Yilin Wang et al., "Research on the Sustainability in Green Building" Advances in Economics, Business and Management Research, volume 215,2022.

This study analyzes the current development of green buildings, revealing a lack of management planning throughout the process. It proposes a green building management planning system to ensure sustainable development from design to completion, addressing urgent problems in green building quality and maintenance.

# Anjali Thakare et al., "Study on Green Building Concept and Materials" International Research Journal of Modernization in Engineering Technology and Science, Volume:04/Issue:04, 2022.

India's rapid urbanization is causing environmental issues in the building industry, including increased energy consumption and carbon content in the air. To address these issues, developers must adopt sustainable building design methods and use locally available, environmentally beneficial materials. This paper presents a list of five green construction materials, including cost efficiency, durability, and energy efficiency, as viable alternatives to traditional materials. These materials are essential for a brighter future.

Step 1	
Literature Review Problem Statement Objectives	
Step 2	
Actual Case study Primary Data Collection	
Step 3	
Preparation of Design and Modelling using Data Collection Prepare Benefit cost & Time analysis for particular case study	CAD
Step 4	
Analysis of Data with Software & Coding Model Testing and Working	
Step 5	
Result and Discussion	
Step 6	
Recommendations	
Step 7	
Paper Presentation and report writing.	
Step 8	
Submission and Approval of Dissertation	

### IV. RESEARCH METHODOLOGY

Figure 1.4: Research Methodology



#### GOAL OF WORK

The aim of this research is to investigate the implementation of Green Building concept among contractors. To study the different construction techniques this is newly used. Identifying Green Building developed barriers. Develop new strategies or make changes on current strategies in order to drive out the barriers.

#### PROBLEM STATEMENT

The construction industry heavily relies on conventional concrete materials, which are associated with significant environmental impacts such as high carbon emissions, resource depletion, and waste generation. While composite and green materials offer potential advantages in durability, environmental sustainability, and energy efficiency, their adoption remains limited due to lack of comprehensive comparative studies and awareness regarding costeffectiveness, structural performance, and lifecycle impacts. This project seeks to address this gap by systematically comparing these materials to provide practical guidelines for sustainable construction.

#### **OBJECTIVES**

- To study the mechanical, thermal, and environmental properties of conventional concrete, composite, and green construction materials.
- To analyze the economic costs involved in the use of these materials over the lifecycle of a building.
- To assess the environmental impact, including embodied energy and carbon footprint, of each material type.
- To evaluate the durability and maintenance requirements of these materials under typical construction conditions.
- To provide recommendations for selecting sustainable materials that balance performance, cost, and ecological benefits in building construction.



Figure1.5: System Architecture

Green Building Products and Materials aim to reduce the environmental impact of construction by promoting the use of renewable resources, enhancing energy and water efficiency, improving indoor air quality, and minimizing waste. These materials are selected based on parameters such as resource efficiency, affordability, recyclability, and durability. The selection process involves surveying technical data, evaluating environmental claims, and using scoring methods to identify the most sustainable options. This approach supports the broader concept of sustainable development—meeting current needs without compromising future generations—especially vital as urban populations continue to grow.

#### System Architecture



Proceedings of International Conference on Innovation & Advancements in Civil Engineering (ICIAC-2025) 15<sup>h</sup> May 2025, Department of Civil Engineering, Ajeenkya D Y Patil School of Engineering, Lohegaon, Pune, India, ISBN: 978-81-984557-3-4

Criteria	Concrete	Composite	Green
	Materials	Materials	Materials
Definition	Cement- based mixture with aggregates and water	Engineered materials made from two or more constituents	Sustainable materials with minimal environment al impact
Material Compositio n	Cement, sand, coarse aggregates, water	Matrix (resin/polym er) + reinforcemen t (fibers: glass, carbon, etc.)	Bamboo, fly ash, recycled plastic, hempcrete, straw bales, adobe, etc.
Strength-to- Weight Ratio	Moderate strength, high weight	High strength, low weight	Varies; bamboo and hempcrete show high strength-to- weight ratio
Durability	Good, but affected by weathering, corrosion	Excellent durability; corrosion and fatigue resistant	Durable if properly treated (e.g., stabilized earth blocks, treated bamboo)
Thermal Insulation	Poor thermal performanc e	Moderate to good	Excellent thermal insulation (e.g., straw bales, hempcrete)
Flexibility	Brittle behavior, limited tensile strength	High flexibility and toughness	Generally good flexibility (especially bamboo, cork)
Corrosion Resistance	Low (steel reinforceme nt prone to corrosion)	High (non- metallic, corrosion- resistant)	Naturally resistant or non- corrosive
Environmen tal Impact	High CO <sub>2</sub> emission from cement production	Moderate to low, depending on fiber/matrix sources	Very low; made from natural or recycled materials
Embodied Energy	High due to cement and steel content	Moderate; lower than concrete in some cases	Very low (especially locally sourced materials like adobe or bamboo)
Constructio	Longer;	Faster with	Varies;

### Comparative Study: Concrete vs Composite vs Green Materials



Proceedings of International Conference on Innovation & Advancements in Civil Engineering (ICIAC-2025) 15<sup>th</sup> May 2025, Department of Civil Engineering, Ajeenkya D Y Patil School of Engineering, Lohegaon, Pune, India, ISBN: 978-81-984557-3-4

n Time	needs curing and formwork	prefabricatio n	some are fast (e.g., modular green panels), some require craftsmanshi p
Maintenanc e	Requires frequent maintenanc e	Low maintenance	Low maintenance (especially when naturally pest/weather resistant)
Cost	Low initial cost, moderate lifecycle cost	Higher initial cost, but efficient long-term	Low to moderate; often economical when sourced locally
Sustainabilit y	Low; resource- intensive and polluting	Moderate; can include recycled or bio-based fibers	High; renewable, biodegradab le, recyclable, locally available
Examples	RCC, PCC, Precast Concrete	FRP, GFRP, CFRP, carbon composites	Bamboo, fly ash bricks, hempcrete, recycled plastic lumber, cork, adobe
Applications	Bridges, roads, foundations , pavements	Aerospace, seismic retrofitting, green facades, cladding	Eco-homes, walls, insulation panels, low- rise buildings, sustainable furniture

### Case Study

### Plan of Building



<u>ناب</u> SkePlan

Figure1.6: Plan of Building


Site Name: Suzlon One earth

- Location: Pune, Maharashtra
- Site Area : 45392m2
- Built-up Area: 70865m2
- GRIHA rating: 5 Stars
- LEAD: Platinum
- The total size of land is 10 acre
- Have divided into 5 blocks
  - Sky lounge
  - Sun lounge
  - Aqua lounge
  - Tree lounge
  - Air lounge

	Land	443,473 sq ft (10.18 acres)
lighlights	Office space	598,256 sq ft
	Terminus (basement)	223,270 sq ft
	Open space (landscape)	185,578 sq ft
	Capacity	2300
-		
a line	A CONTRACTOR OF THE	



#### Passive architectural design

- Orientation: Facades of the building face north, south, north-west and south-east.
- 100% shading by external louvers on first and second floor.
- Small terraces created in all blocks to promote interaction with external environment.

#### Aim of Suzlon One Earth

- Sustainability- a way of life
- To create a truly inspiring place to work.
- To optimize use of natural resources.



#### V. MATERIAL

#### 15% of cement is replaced with fly ash.

Post-tensioning slab. Bamboo flooring. Low VOC paints.

100% powered by combination of onsite and offsite renewable energy source.

6% of total energy consumption comes from onsite. Remaining energy from offsite suzlon wind turbines. Overall, 50% electricity is saved.

#### **Renewable Energy Technologies Installed on site**

- ➤ Solar energy Installed capacity is 13.44W.
- ➤ Wind energy 18 windmills of 4.75kW capacity each.
- > 250000 unit of electricity generated annually

#### **HVAC & Ventilation**

- ➤ Installation of water cooled VRC saving 40% energy.
- ➤ Treated fresh air unit are installed.
- ▶ Installation of CO2 sensor.
- > High efficiency mechanical system to reduce energy consumption.

#### Water & Sanitation

- Rain water harvesting tank capacity = 1000 cum.
- Separate water treatment plant 240 m3/day used HVAC, gardening, flush.
- 100 cum/day solar water heating system- Save 1.4lakh kWh of electricity annually.

#### Water and Sanitation

- > All vegetation is native species- 50% water is conserved.
- Sewage treatment plan of capacity 120cum/day.
- > Zero discharge of waste water into natural stream.
- > Landscape area above slab is provide with pipeline for collection of storm water.

#### Waste Management.

- Zero waste management policy.
- > Waste segregation system in provided.
- > Organic waste is converted into manure by OWC of capacity 100kg/hr.
- > Electrical & electronics waste is treated through Pollution Control Board.
- > Recyclable material is sent for recycling.

#### **Green Transport**

- > Carpooling is encouraged by providing 5% dedicated parking areas.
- ► Electrical Vehicles.
- > Dedicated spaces for cycle parking in the premises.

#### Conclusion on case study

- 100% renewable energy is utilized.
- Overall, 50% of electricity is save.
- 250000 unit of electricity generated annually.





• Zero waste management system.

#### **VI. CONCLUSION**

The comprehensive literature review highlights the growing global emphasis on integrating sustainable design principles within the built environment, particularly through the adoption of green building concepts. Studies across various regions, including India, Jordan, Ghana, and China, consistently underline the importance of aligning green construction with broader environmental goals such as the United Nations Sustainable Development Goals (SDGs). Despite a notable increase in awareness and academic exploration, several gaps persist — ranging from inadequate policy support, lack of practical implementation strategies, underutilization of technologies like AI and BIM, to region-specific challenges such as limited stakeholder engagement and the need for customized green building rating systems.

Most researchers agree that while frameworks such as LEED, GRIHA, and IGBC provide a strong foundation, their practical adoption remains limited due to economic, technical, and educational barriers. Furthermore, the integration of renewable energy, AI-enhanced design, and smart material selection is still in its nascent stage and requires robust policy backing and cross-disciplinary collaboration.

It is evident that future efforts must focus on bridging these research gaps through interdisciplinary approaches, policy refinement, real-time performance evaluations, and inclusive education. Emphasis should also be placed on region-specific adaptation of green technologies, capacity building, and the creation of smart, human-centric, and resource-efficient infrastructures. This evolution of green building practices is crucial not just for environmental preservation but also for ensuring long-term economic and social sustainability.

#### ACKNOWLEDGEMENT

It gives me an immense pleasure and satisfaction to present this Research Paper on "Green Building Design" which is the result of unwavering support, expert guidance and focused direction of my guide Asst. ......... and Project coordinator ......, to whom I express my deep sense of gratitude and humble thanks to ......, H.O.D. for his valuable guidance throughout the presentation work. The success of this Research Paper has throughout depended upon an exact blend of hard work and unending co-operation and guidance, extended to me by the supervisors at our college. Further I am indebted to our principal ...... whose constant encouragement and motivation inspired me to do my best.

Last but not the least, I sincerely thank to my colleagues, the staff and all other who directly or indirectly helped me and made numerous suggestions which have surely improved the quality of my work.

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# Partial Replacement of the Cement by Eggshell and Sawdust Powder in Concrete

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ABSTRACT: Solid waste management is one the leading problems faced by developing nations. In Asia, the average per capita generation of municipal waste is about 0.85 kg per person per day, and this number is only expected to raise as the population grows and nation becomes more industrialized. One of the wastes is eggshell waste, as Malaysians have among the largest egg consumption in the world. This paper presents the properties of cement mortar with fine eggshell powder as partial replacement of cement. Type-N mortar was prepared with cement: sand: water ratio of 1: 2.75: 0.60 and the percentages of cement replacement tested are 2.5%, 5%, 7.5% and 10% by weight of cement. Flow table test was conducted to access the fresh properties of mortar, while compressive test and flexural test were carried out to deter- mine the mechanical properties. Water absorption and acid resistance eggshell mortar were also studied. From the result, eggshell mortar has similar flow consistency with the control. 5% eggshell produces mortar with optimal compressive and flexural strength and the water absorption of eggshell mortar is lower compared to control. However, eggshell mortar loses more weight when subjected to acid attack. The incorporation of alternative materials into cement has gained attention due to environmental concerns and the need for sustainable construction practices. Sawdust and eggshell powder are two such materials that can be used as partial replacements in cement to improve certain properties while reducing waste. Sawdust, a byproduct of the wood industry, is lightweight and can enhance the insulation properties of cement. When properly treated, it can also reduce the density of concrete, making it useful for non-load-bearing structures.

**KEYWORDS**: Eggshell powder, Sawdust powder, Cement replacement, Sustainable Concrete, Eco friendly material, Waste utilization.

#### I. INTRODUCTION

Concrete is a composite material which is good in compressive strength but weak in tensile strength. At present for a variety of reasons, the concrete construction industry is not sustainable. The reason is firstly, it consumes huge quantities of virgin materials which can remain for next generations. Secondly, the principal binder in concrete is Portland cement, the production of which is a major contributor to greenhouse gas emissions which results in global warming and climate changes. 900 kg of CO2 is emitted for production of per ton of cement. The production of cement also uses the natural lime in large quantity which results in scarcity of natural resources in future.

India is in fifth position of world annual egg production. About 2 million tones of egg shell is being wasted annually as landfills. The aim of this study is to find the changes in the properties of concrete due to addition of environmental waste-egg shell powder and egg albumen. The egg shell powder is added as partial replacement of cement because the egg shell is highly rich in calcium which is mostly similar to calcium carbonate (Caco3) used for the manufacturing of cement. the egg albumen is of 2/3 of weight of egg with 90% of it contains water and the remaining 10% is of proteins and fats. The cubes are tested for 7days, 14days and 28 days. compressive strength and prisms are tested for 7days and 28 days for its flexural strength.







#### **II. RELATED WORK**

#### **Compressive Strength Results**

Cube test results after 28 days of curing:

Cube No.	Age	Load (kN)	Compressive Strength (N/mm <sup>2</sup> )
1		540	24.00
2	7 Days	579	25.70
3		554	24.46
4	14 Days	732	32.53



5		748	33.24
6		728	32.35
7		1007	44.75
8	28 Days	1000	44.44
9		922	40.97

#### Table No.1.3: Compressive Strength Result

Average Strength (Set 1 = 1,2,3): 24.73 N/mm<sup>2</sup> Average Strength (Set 2 = 4,5,6): 32.71 N/mm<sup>2</sup> Average Strength (Set 2 = 7,8,9): 43.38 N/mm<sup>2</sup> Overall Average: 34.62 N/mm<sup>2</sup>

Result: PASS(As per IS 516 – 1959 the minimum requirement is 20 N/mm<sup>2</sup> at 28 days)





#### III. METHODOLOGY

The methodology for using eggshell powder & Saw dust powder as a partial replacement in cement involves collecting and cleaning waste eggshells, followed by drying and grinding them into a fine powder. The powder is then sieved to ensure uniform particle size. A mix design is developed, replacing a portion of the cement with eggshell & sawdust powder (e.g., 2.5%, 5%, 7.5%, or 10%). Concrete is prepared by mixing the powder with other standard ingredients, cast into molds, and cured for a specified time. After curing, the specimens undergo tests such as compressive strength and workability to evaluate the impact of eggshell powder & sawdust powder on performance.

Results are analyzed to determine the optimal replacement percentage.





#### **IV. EXPERIMENTAL RESULTS**

Slump tests showed initial workability of 180 mm, reducing to 110 mm after 60 minutes. Compressive strength results after 28 days showed an average of 43.38 N/mm<sup>2</sup>, surpassing the required M30 grade strength. The optimal mix was found with 5% eggshell powder and balanced sawdust content. Egg albumen contributed to reduced permeability and a smoother finish.



The control mix has high initial workability but rapid slump loss, which may cause issues if delays in placement occur. The modified mix, while slightly less workable at the start, shows better retention of workability over time. This suggests the modified mix may be more suitable for practical site conditions where delays happen. However, slump alone isn't enough – this should be correlated with strength, setting time, and durability for a full conclusion.

The compressive strength results show the concrete successfully meets and exceeds the required 28-day strength for M30 grade. Passes structural safety requirements. Some variability between cube sets exists, so consistency in mixing, casting, and curing should be reviewed. The admixture appears to contribute positively to strength development (especially in Set 2).

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### Performance based Seismic Analysis of G+9 Storey Building using ETABS and Pushover Method

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**ABSTRACT**: The increasing frequency and intensity of earthquakes highlight the urgent need for structures that can withstand seismic forces without significant damage or loss of life. Performance-based seismic design (PBSD) has emerged as a reliable framework for evaluating the real behavior of structures under earthquake loads. This study focuses on the performance-based seismic analysis of a G+9 storey reinforced concrete (RC) building using ETABS software and the pushover analysis method. The building model is designed as per IS 456:2000 and IS 1893 (Part 1): 2016 seismic codes, considering Zone III seismic conditions. Non-linear static pushover analysis is conducted to determine the building's capacity and performance under increasing lateral loads that simulate earthquake effects. The capacity curve (base shear vs. roof displacement) and performance level (Immediate Occupancy, Life Safety, or Collapse Prevention), and critical structural elements. Results indicate how the building behaves under seismic loading and whether it meets desired performance objectives. The study demonstrates that pushover analysis is an effective tool for assessing seismic performance and can guide retrofit strategies and design improvements. This research underscores the importance of integrating performance-based methods into the design and evaluation of mid-rise buildings in seismic regions to ensure structural safety and resilience.

**KEYWORDS**: Performance-Based Seismic Design (PBSD), Pushover Analysis, ETABS, Nonlinear Static Analysis, G+9 Storey Building, Seismic Performance, Plastic Hinges, Capacity Curve, Structural Evaluation, Earthquake-Resistant Design, Base Shear, Roof Displacement, IS 1893:2016, RC Building, Performance Point.

#### I. INTRODUCTION

In urban construction, high-rise buildings are subjected to various types of forces, including seismic forces that can compromise structural integrity. Ensuring that buildings perform optimally under such forces is a key concern for engineers. Traditional design methods focus on meeting code-prescribed safety requirements. However, performance-based design (PBD) shifts the focus toward evaluating the structure's ability to perform under extreme seismic events. The pushover analysis method, a type of nonlinear static analysis, helps assess the seismic performance of a building by simulating its response under increasing earthquake loads.

Designing a G+9 storey building requires a robust and reliable method to ensure its structural integrity, safety, and resilience under various load conditions, particularly seismic loads. In modern structural engineering, performance-based design is gaining prominence as it allows for a more comprehensive and customized approach to meeting safety, functionality, and resilience objectives.

The Performance-Based Design (PBD) approach moves beyond traditional design codes and prescriptive requirements, focusing on how a building performs under real-world conditions, particularly when subjected to extreme forces such as earthquakes. By using performance-based methods, designers can assess the building's ability to resist and withstand such loads, ensuring safety and operational functionality throughout its lifespan.

For this kind of design, ETABS (Extended Three-Dimensional Analysis of Building Systems) is a powerful software tool that allows engineers to model, analyze, and design buildings subjected to a variety of loads. ETABS is widely used for structural analysis and design of buildings, especially in urban settings where seismic safety is a priority.

#### II. RELATED WORK

Numerous studies have been conducted on performance-based seismic analysis using pushover methods to evaluate the nonlinear behavior of multi-storey structures under earthquake loads. The evolution of performance-based design approaches, particularly after the introduction of guidelines such as FEMA 273/356 and ATC-40, has significantly influenced the seismic assessment of buildings.



1. Deosarkar and Gowardhan (2015) - Seismic Performance of Combined Isolation System for Asymmetric Buildings Using Non-Linear Time History Analysis used ETABS to evaluate the effects of different base isolation systems High Damping Rubber Bearings (HDRB), Lead Rubber Bearings (LRB), and Friction Pendulum Systems (FPS) on asymmetric G+5 structures. 2. Reddy and Madhu (2018) - Design Results of a Multi-storied Building using STAAD PRO and ETABS for Regular and Irregular Plan compared the behavior of regular and irregular plan buildings in both STAAD.Pro and ETABS. Their study highlighted ETABS's advantage in handling irregular geometries and complex layouts due to its user-friendly interface and advanced modeling capabilities. 3. Fardeen Khan and Preeti Agarwal (2022) - Design & Analysis of Multi Storeved Building (G+10) Using ETAB focused exclusively on the use of ETABS to design and analyze a G+10 building. Their work highlighted the increasing importance of wind loads over seismic loads in governing structural behavior. 4. Del Rey Castillo et al. (2024) - Seismic Retrofitting of Realistic Beam-Column investigated the retrofit of deficient beam-column joints in RC buildings using FRP sheets and anchors. Their case study emphasized the importance of retrofitting strategies for older buildings lacking sufficient shear capacity, especially in seismic zones.. 5. Kasilingam & Arivumangai (2024) - G+9 Educational Building Design The authors designed a G+9 educational structure incorporating workspaces, conference halls, and administrative cabins. The methodology involved manual calculations based on IS875 Part-2 for loads and structural design using limit state principles. ETABS was used for 3D modeling and analysis. The study emphasized durability, safety, and economic feasibility while providing detailed construction drawings.

#### **III. METHODOLOGY**

Designing a G+9 storey building with a performance-based approach involves several stages, from modeling the structure to performing a pushover analysis and interpreting the results. Below is a detailed methodology for using ETABS software and the pushover analysis method in the design of the building.

#### 1. Conceptualization and Planning

The first step in the methodology is to understand the project scope and the requirements for the performance-based design. This includes determining the seismic zone, the building's intended use (residential, commercial, or mixed), and the performance objectives. In performance-based design, the focus is on how the structure will perform under realistic loading conditions, particularly seismic forces.

#### 2. Structural Modeling in ETABS

Once the design parameters are defined, the next step is to create a detailed structural model in ETABS. The software is used to simulate the behavior of the building under different loading conditions, including gravity loads, live loads, and seismic forces.

#### 3. Perform Linear and Nonlinear Analysis

Before proceeding with the pushover analysis, run a linear dynamic analysis (e.g., response spectrum analysis) to evaluate the building's initial seismic response and get the fundamental periods and mode shapes.

#### 4. Push-Over Analysis Execution

After defining the nonlinear hinges and load distributions, the pushover analysis can be performed. This involves gradually applying lateral forces to the building until it reaches the failure point or until the displacement exceeds acceptable limits.

#### 5. Interpretation of Results

Once the pushover analysis is completed, the results are analyzed to assess the performance of the building under seismic forces.

#### 6. Design Refinements Based on Analysis

If the pushover analysis indicates that the building does not meet the desired performance objectives, the design is refined through several methods.

#### 7. Final Design Validation

Once the necessary design modifications are made, a final validation of the building's performance is done using ETABS

#### 8. Documentation and Reporting

After the design process is completed, the final step is to document the entire analysis and design process in a detailed report.



#### **IV. EXPERIMENTAL RESULTS**



#### Symmetric Plan



Unsymmetric Plan





License #\*1UANEHGTG66DZKP



ETABS 20.1.0

Story Response - Maximum Story Drifts

Summary Des	cription		
This is story resp	onse output for a specified range of stor	ies and a selected load case or lo	ad combination
Input Data			
Name	With Floating Column		
Display Type	Max story drifts	Story Range	All Stories
Modal Case	Modal	Top Story	W.T.T.S1
Mode Number	1	Bottom Story	BASE



ETABS 20.1.0

Plot

Story Response - Maximum Story Drifts

Summary Descri This is story es and a sel ted load ca Input Data Name Display Type Max story drifts Modal Case Modal Mode Number 1









#### V. CONCLUSION

Designing a G+9 storey building using a performance-based approach with ETABS and the pushover analysis method provides a comprehensive understanding of the building's structural behaviour under seismic loads. The process facilitates a more resilient and safety-focused design by identifying potential weak points and ensuring that structural elements are proportioned and reinforced adequately to withstand anticipated loads. Through pushover analysis, the following key insights and benefits are achieved:

**Enhanced Seismic Performance:** The pushover analysis allows for precise evaluation of how the building responds to increasing lateral loads, ensuring it meets desired performance levels, such as Immediate Occupancy, Life Safety, or Collapse Prevention, based on the design criteria.

**Informed Plastic Hinge Distribution:** The analysis identifies where plastic hinges are likely to form under severe loading. This enables the "strong column-weak beam" approach, promoting a controlled failure mechanism that prioritizes life safety by preventing column failures.

**Efficient Structural Design:** Performance-based design reduces overdesign and provides optimal material usage, as the structure is tailored to meet specific performance objectives rather than following prescriptive code methods alone. **Safety and Resilience:** The building is designed to perform reliably under extreme events, minimizing risk of collapse and enhancing resilience, particularly for regions prone to seismic activity.

**Compliance with Codes:** Using ETABS to perform pushover analysis ensures compliance with modern seismic codes, contributing to a robust and durable building design.

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# Analysis on Self-Healing Concrete by using Bacillus Bacteria

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**ABSTRACT:** Concrete is widely used in construction all over the world. However, over time, buildings like bridges, tunnels, and dams develop cracks and need repair. One solution is self-healing concrete, which can fix its own cracks. This helps reduce maintenance and repair work. Adding Bacillus bacteria to concrete makes it stronger and more durable. Adding Bacillus bacteria to concrete allows it to repair itself, which can improve the lifespan and strength of concrete structures. Self-healing concrete is an innovative material designed to repair its own cracks and improve the durability of structures. This study focuses on the use of Bacillus bacteria to enhance the self-healing properties of concrete. When cracks occur, the bacteria become active upon contact with moisture and produce calcium carbonate (CaCO<sub>3</sub>), which fills the cracks and restores the material's strength. The analysis includes the preparation of bacterial concrete, comparison with conventional concrete, and evaluation through compressive strength and crack-healing tests. Results show that bacterial concrete exhibits improved healing capacity, increased strength, and enhanced durability. This technology offers a sustainable and cost-effective solution for reducing maintenance in concrete structures.

KEYWORDS: Self healing, Concrete, Bacillus Bacteria, Compression Test, Water-Cement Ratio

#### I. INTRODUCTION

Concrete is preferred in construction because it is affordable and flexible in design. But it is also prone to cracking, which happens due to stress or environmental effects. While small cracks may not be dangerous, they allow harmful chemicals to enter and damage the concrete and steel inside. This reduces the strength and durability of the structure.

To overcome this, self-healing concrete has been developed, inspired by how living things heal themselves. This type of concrete can repair its own cracks, improving strength and reducing the need for repairs.

#### **II. OBJECTIVES OF THE STUDY**

- 1. To compare the variations of % of bacteria and to find out the most and effective one.
- 2. To compare the compressive strength in different % of bacteria
- 3. To study the workability of concrete mixed with different amounts of bacteria

#### **III. METHODOLOGY**

- Data was collected from research papers and online sources.
- Concrete cubes (150mm x 150mm x 150mm) were made using M25 grade concrete.

15 cubes were prepared:

- (a) 3 cubes had no bacteria.
- (b) 4 cubes had 0.5% Bacillus bacteria.
- (c) 4 cubes had 1% bacteria.
- (d) 4 cubes had 1.5% bacteria.
  - Water-cement ratios used: 0.45, 0.5, 0.6.
  - All cubes were cured for 28 days.
  - After curing, compressive strength tests were performed.
  - Cracks were observed to see if they healed naturally over 28 days.





#### **IV. MATERIAL ESTIMAION**

Mould Size: 150mm x 150mm x 150mm
 Volume of One Mould: 0.003375 m<sup>3</sup>
 Total Number of Moulds: 15
 Total Volume of Moulds/Concrete: 0.050625 m<sup>3</sup>
 Dry Volume of Concrete: 0.0779625 m<sup>3</sup>
 Mix Ratio: M25 (1:1:2 for Cement: Sand: Aggregate)

#### **Material Quantities:**

1.Cement: 28 kg 2.Sand: 31.5 kg 3.Aggregate: 61.5 kg

#### **Cost Estimate:**

1.Cement OPC 53 (50kg bag): Rs 500 2.Sand: Rs 150 3.Aggregate: Rs 290







Cement



Sand



**Bacillus Bacteria** 





#### **Concrete Mix**

#### V. RESULTS

#### Compressive Strength Test

Sr. No.	Cube No.	% Of Bacteria	W/C Ratio	Compression Test Values (KN)
1	P-1	0%	0.45	750
2	P-2	0%	0.50	800
3	P-3	0%	0.60	780
4	P-4	0.5%	0.45	840
5	P-5	0.5%	0.50	880
6	P-6	0.5%	0.60	850
7	P-7	0.5%	0.50	
8	P-8	1%	0.45	870
9	P-9	1%	0.50	950
10	P-10	1%	0.60	900
11	P-11	1%	0.50	
12	P-12	1.5%	0.45	1000
13	P-13	1.5%	0.50	1050
14	P-14	1.5%	0.60	1050
15	P-15	1.5%	0.50	







#### **Compressive Strength Test Results:**

- 0.5% Bacillus bacteria  $\rightarrow$  10% increase in strength
- 1% bacteria  $\rightarrow$  18.75% increase
- 1.5% bacteria  $\rightarrow 31.25\%$  increase

This shows that more bacteria leads to higher strength

#### **VI. CONCLUSION**

Introducing the bacteria into the concrete makes it very beneficial it improves the property of the concrete which is more than the conventional concrete. Adding Bacillus bacteria to concrete makes it stronger and more durable than regular concrete. The bacteria produce calcium carbonate, which fills in the cracks and strengthens the structure. Studies show a clear improvement in strength with the addition of bacteria, especially at 1.5%, which gave the best results. The workability of self-healing concrete can be influenced by the water-cement ratio. As the w/c ratio increases the workability of concrete increases.

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# A Comparative Analysis on the Optimisation of BIM over CAD

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**ABSTRACT**: Building Information Modeling (BIM) represents a transformative approach to project development, particularly within the architecture, engineering, and construction (AEC) industries. Despite its innovative potential, many professionals still predominantly rely on Computer-Aided Design (CAD), a more established and widely understood toolset. BIM introduces a data-rich, collaborative environment that extends beyond traditional design, offering multidisciplinary insights that empower architects and designers to engage more holistically across various project stages. By integrating detailed metadata and intelligent components, BIM facilitates enhanced decision-making, coordination, and efficiency throughout a building's lifecycle. This research seeks to analyze and contrast the operational dynamics of CAD and BIM technologies. We conducted a comparative study by reviewing existing literature and analyzing real-world case studies to evaluate how each system supports architectural design processes. Our goal is to identify how these platforms differ in terms of workflow efficiency, collaboration, and data integration, ultimately determining which technology offers a more streamlined and effective design methodology. Through this analysis, we aim to provide guidance on the optimal application of each system, ensuring professionals can align their tools with the specific demands of their projects and enhance overall productivity.

**KEYWORDS**: Comparative Analysis, BIM Workflow, CAD, Architecture Modelling.

#### I. INTRODUCTION

Building Information Modeling (BIM) offers significant advantages throughout the architectural design process. It not only enhances productivity but also enables innovative design strategies that were previously difficult to achieve using conventional methods. In contrast, Computer-Aided Design (CAD) was traditionally limited to two-dimensional drafting and representation. Over time, CAD evolved to include basic 3D modeling; however, it lacked the integration of embedded data and collaborative functionalities that define BIM.

BIM introduces a holistic approach to design and construction, where models are enriched with comprehensive information — from structural details to material specifications — allowing for more informed decision-making and seamless coordination across disciplines. This paradigm shift supports integrated workflows and opens up new possibilities for cross-functional collaboration across the architecture, engineering, and construction domains.

The architectural sector, which plays a crucial role in shaping the built environment, must continually evolve to stay aligned with emerging technologies. Recognizing this, various governmental bodies have begun to mandate BIM adoption as part of modern construction standards and regulatory compliance. However, as with the early introduction of CAD, the transition to BIM has been met with skepticism and logistical challenges.

Many industry professionals question whether BIM is fully compatible with their existing workflows and hardware infrastructure. These concerns mirror the resistance experienced during the CAD era, particularly regarding system adaptability and implementation feasibility.

Within architectural firms, workflow refers to the collaborative process of integrating diverse areas of expertise into a unified design methodology. Transitioning to a BIM-based workflow is often complex, requiring alignment of tools, skill sets, and data handling capacities. One key challenge lies in the management and storage of extensive project data, which can strain current software and hardware capabilities.

BIM addresses these limitations by offering a centralized, digital environment that supports simultaneous data input and access across multiple disciplines. This centralized data model enhances traceability, version control, and project transparency.

Therefore, the focus of this research — "A Comparative analysis on the optimisation of BIM over CAD" — is to systematically compare the BIM workflow with the traditional CAD approach within the context of architectural



practice. The study aims to evaluate each system's impact on collaboration, efficiency, and project outcomes to determine the most effective and future-ready design methodology.

#### **II. RELATED WORK**

The evolution of design technologies in the Architecture, Engineering, and Construction (AEC) industry has prompted extensive research comparing Building Information Modeling (BIM) and Computer-Aided Design (CAD) to evaluate their respective efficiencies, workflows, and practical applications. A study titled "BIM for Enhanced Collaboration and Lifecycle Integration" investigated five large-scale public and financial sector projects, focusing on the use of BIM throughout the design, construction, and operational phases. The research concluded that BIM significantly improves productivity through better information sharing, integration, and collaboration among stakeholders. In the paper "Comparative Analysis of BIM and CAD in Civil Engineering", the authors conducted a comprehensive review through literature studies, case evaluations, and expert interviews to explore the fundamental capabilities and performance of both BIM and CAD. The study acknowledged BIM's strengths in integrated design and collaborative workflows while recognizing CAD's precision and flexibility across various engineering applications, ultimately recommending the selection of tools based on project-specific needs. Another research effort, "Evaluating BIM for Quantity Take-Off in the New Cycle Building Project", presented a case study where inconsistencies in material quantity estimations using CAD led to the late-stage implementation of BIM for QTO (Quantity Take-Off). The paper utilized tools such as the Delphi Method and Analytical Hierarchy Process (AHP) to evaluate BIM's effectiveness compared to CAD, and concluded that BIM offers enhanced control, accuracy, and decision-making support, although challenges such as high costs and required training limit its widespread adoption. Similarly, the study "Impact of BIM on Reducing Errors and Project Costs" focused on real-world construction challenges such as design changes, communication gaps, and repetitive work that lead to budget overruns and quality compromises. Through side-by-side project comparison, it was found that BIM substantially reduces errors and omissions in construction documents (up to 64%) and decreases repetitive work by 43%, while also cutting down project cost and duration, strongly advocating BIM integration across all construction stages. Lastly, the paper "Workflow Comparison Between BIM and CAD in Architectural Design" specifically addressed the practical differences in workflows between the two technologies. By examining case studies and literature, the study highlighted how BIM facilitates a more coherent and streamlined design process by providing informative data and multidisciplinary coordination, in contrast to CAD's more linear and manually controlled drafting process.

Together, these studies contribute to a growing body of evidence that supports the implementation of BIM over CAD for improved efficiency, accuracy, and collaboration in construction workflows. However, they also collectively acknowledge the practical constraints associated with BIM adoption, such as software complexity, cost, and the need for professional training—issues that must be addressed for broader industry-wide implementation.

#### **III. METHODOLOGY**

This study adopts a structured, four-phase methodology to evaluate the optimization benefits of Building Information Modeling (BIM) compared to traditional Computer-Aided Design (CAD) systems. Initially, a suitable construction or infrastructure project site is selected based on the availability of both CAD and BIM documentation. Data collection involves gathering primary information from project drawings, 3D models, expert interviews with architects and engineers, and reviews of past reports. Secondary data includes software performance logs, clash detection records, and material quantity outputs, which support benchmarking efforts. In the next phase, detailed workflows are mapped for both BIM and CAD platforms, documenting every critical task from design to execution—such as modeling, clash detection, quantity take-off, and scheduling. Quantitative metrics including modeling time, estimation accuracy, coordination efficiency, rework rates, and stakeholder collaboration are analyzed using tools like Autodesk Revit, AutoCAD, and data analysis software such as MS Excel and SPSS.

A comparative analysis is then conducted through a side-by-side evaluation matrix that examines both systems on parameters like time and cost efficiency, flexibility to design changes, collaboration quality, and resource optimization. Visual and statistical analyses help identify performance trends and draw data-driven inferences, complemented by expert feedback and industry benchmarks. Finally, findings are compiled into a structured report that includes visual summaries such as tables, charts, and 3D model snapshots. The report highlights key observations, discusses deviations, and provides actionable recommendations for improving digital workflows. Additionally, it outlines the study's limitations and proposes future research directions in the evolving field of construction digitization.



#### **IV. EXPERIMENTAL RESULTS**

This experimental study was undertaken to comparatively assess Building Information Modeling (BIM) and traditional Computer-Aided Design (CAD) systems with respect to four key performance parameters: time efficiency, cost optimization, collaboration, and overall project efficiency. The primary objectives were to analyze functional differences, evaluate productivity, study the impact of BIM on collaborative workflows, and identify optimization techniques that allow BIM to outperform CAD. A mid-scale commercial building project was selected for a controlled simulation using both systems. Project teams were assigned parallel tasks in modeling, coordination, and estimation using either CAD or BIM platforms.

During the course of the simulation, several challenges surfaced, particularly in CAD-based workflows. CAD led to time inefficiencies due to repetitive manual drafting, disjointed data inputs, and frequent inter-disciplinary clashes that were only identified during late-stage reviews. Cost estimation in CAD was prone to inconsistencies due to the absence of real-time quantity take-off and material linking. Additionally, collaboration among team members was fragmented, relying heavily on emails and static drawings, which led to miscommunication and delays. In contrast, BIM provided a centralized, data-rich environment where tasks like clash detection, automated scheduling, and live quantity take-off were integrated. This enabled real-time collaboration between architects, structural engineers, and MEP consultants. Quantitative results showed that BIM improved time efficiency by 33%, enhanced cost optimization by 25%, and increased collaboration efficiency by 40% when compared to CAD. Overall project efficiency saw a 30% rise in performance under BIM workflows. These outcomes support the argument that BIM is significantly more effective in modern construction environments, offering superior integration, reduced rework, and better-informed decision-making compared to traditional CAD systems.



#### V. CONCLUSION

Building Information Modeling (BIM) and Computer-Aided Design (CAD) constitute fundamentally different paradigms tailored to diverse project exigencies. BIM's parametric, data-integrated environment facilitates multidimensional modeling, interdisciplinary collaboration, and dynamic project control, optimizing complex workflows and lifecycle management. Conversely, CAD provides a deterministic, geometry-centric platform well-suited for linear, detail-focused design processes requiring precision drafting and documentation.

While CAD operates within a segmented and less integrated framework—lacking inherent mechanisms for synchronized time and cost analytics—its utility persists for projects with defined scope and limited complexity. BIM's capacity for centralized data aggregation, real-time coordination, and semantic interoperability underscores its superiority in driving comprehensive project efficiency and knowledge retention.



Ultimately, the selection between BIM and CAD should be predicated on rigorous project analysis, ensuring alignment with technical requirements and strategic objectives to harness the optimal modeling framework for enhanced delivery and operational performance.

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## **Comparative Design and Analysis of Howe Truss using IS and AISC**

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**ABSTRACT:** The purpose of this study is to compare the structural design and analysis of a Howe truss using two widely accepted design standards: the Indian Standard IS 800:2007 and the American Institute of Steel Construction (AISC) Load and Resistance Factor Design (LRFD), implemented in STAAD.Pro. The aim is to evaluate the efficiency, economy, and safety of both standards through a comprehensive design procedure using STAAD.Pro structural analysis software. Load combinations including dead, live, and wind loads are considered as per the respective codes. Member selection, deflection, base shear, and material utilization are compared. The results highlight the differences in section selection, safety factors, and cost-effectiveness between the two codes using STAAD.Pro's automated analysis and design environment.

**KEYWORDS:** Howe truss, AISC Standards, Comparative Design

#### I. INTRODUCTION

Trusses are fundamental structural elements used in roofs, bridges, and industrial sheds due to their high strength-toweight ratio. The Howe truss, characterized by vertical members in tension and diagonals in compression, is preferred for its simplicity and efficiency. The selection of design codes significantly influences the overall safety and cost of the structure. This paper explores and compares the Indian IS 800:2007 and American AISC LRFD codes to design the same Howe truss structure using STAAD.Pro software. Understanding the differences between these standards is critical for structural engineers working in multinational environments.

This paper shows the comparison between two steel standards i.e. IS and AISC with various load combinations including dead load, live load, wind load which are considered as per the respective codes. Member selection, displacement, material utilization are compared.

#### **II. RELATED WORK**

Previous studies have compared IS and AISC codes for beam and frame structures, showing that AISC often leads to lighter sections due to lower safety factors and more accurate load considerations. However, fewer studies focus specifically on truss structures. Research by Sharma et al. (2019) emphasized cost differences in roof trusses using IS and Eurocode. Similarly, Patel and Shah (2021) found significant design discrepancies between IS and AISC for portal frames. This paper builds upon such studies by focusing solely on Howe truss design using STAAD.Pro.

#### **III. METHODOLGY**

A Howe truss of 16 meters span with a 4-meter rise was modeled and analyzed using STAAD.Pro. The truss was designed under both IS 800:2007 and AISC LRFD standards. The assigned loads included dead load, live load, and wind load as per the respective codes. The design under AISC was carried out using English units, while the IS-based design was done in metric units. Different section types were assigned to the truss members in each case, and iteratively modified until a safe and code-compliant design was achieved. The software's automatic design and code checking tools were utilized to optimize member selection and evaluate structural responses such as deflection, axial force, and utilization ratio.

#### **IV. EXPERIMENTAL RESULTS**

Following graphs shown the displacement comparison between design of IS and AISC in X, Y, and Z direction. It has seen that IS code leads to much higher displacement nearly in all the direction.





Fig. 1: Displacement comparison of IS and AISC design in X direction



Fig. 2: Displacement comparison of IS and AISC design in Y direction

 Proceedings of International Conference on Innovation & Advancements in Civil Engineering (ICIAC-2025)

 15th May 2025, Department of Civil Engineering, Ajeenkya D Y Patil School of Engineering, Lohegaon, Pune, India, ISBN: 978-81-984557-3-4

 Comparison in Z direction



Fig. 3: Displacement comparison of IS and AISC design in Z direction

#### V. CONCLUSION

The displacement comparison between IS and AISC codes shows that IS-coded structures experienced significantly higher displacements in all directions (X, Y, Z). This confirms that the AISC sections used were comparatively stiffer and more efficient in controlling structural movement. Thus, we have successfully identified the performance variation between the two codes, meeting our objective of evaluating displacement behavior.

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### **Upgradation of National Highway to Double Tier Elevated Corridor for Efficient Traffic Management**

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**ABSTRACT:** The upgradation of National Highway to a double-tier elevated corridor represents a transformative approach to enhancing traffic management and alleviating congestion in densely populated urban areas. This study explores the feasibility, design principles, and anticipated benefits of implementing a dual-level highway structure, specifically focusing on its potential to segregate fast-moving and local traffic. The upper tier is designed to accommodate long-distance, high-speed vehicles, while the lower tier serves local traffic, thereby optimizing traffic flow and reducing bottlenecks. The research employs traffic flow theory, urban planning principles, and advanced engineering techniques to assess the project's viability. Data from traffic surveys, demand forecasting, and simulation models provide a comprehensive understanding of current and projected traffic patterns. The findings suggest that such an infrastructure upgrade can significantly improve travel times, enhance safety, and promote sustainable urban development. Additionally, the integration of intelligent transportation systems (ITS) within the elevated corridor framework offers real-time traffic management capabilities, further augmenting efficiency. This study concludes that the double-tier elevated corridor is a viable solution for modernizing national highways and addressing the challenges of urban traffic congestion, ultimately contributing to more efficient and sustainable transportation networks. The study encompasses a multidisciplinary approach, incorporating traffic engineering, urban planning, environmental science, and stakeholder engagement.

As urbanization and population growth continue to place unprecedented demands on transportation infrastructure, the upgradation of national highways to double-tier elevated corridors has emerged as a strategic solution to address the challenges of congestion and inefficiency. This research endeavors to explore the comprehensive planning, design, and implementation of a double-tier elevated corridor, focusing on its potential to revolutionize traffic management on a national scale.

#### I. INTRODUCTION

Traffic congestion is one of the most visible, pervasive, and immediate transport problems plaguing not only India's but also most of the cities of the world on a daily basis. It affects all modes of transportation especially roads and all socioeconomic groups. Rapid population growth, increasing urbanization, inadequate/unplanned transport infrastructure, poor public transport systems and the rising number of personnel vehicles are some of the primary causes of congestion. This article reviews the findings of studies based on road traffic congestion.

Traffic Congestion or traffic jams is one of the major issues in most metropolitan cities like Pune. As we know Pune city is a well-developed and popularly known for Oxford for east for its education many students come from different cities secondly many young people come for jobs because of booming IT companies. Due to this city has become densely populated. Today the Pune's population is around 35 lakhs. Registered vehicles are 36.2 lakh which is exceeding the human population. During the peak hours i.e. 09:00 to 11:00 in the morning and 6:00 to 8:00 in the evening traffic situation gets worst and chaotic. For the Increasing Traffic widening of road is not only the solution as there is land to be accrued in the cities. Land acquisition is a tedious and time consuming process which is not feasible in the cities as well as in the outskirt, so we have to find the sustainable solution for the increasing traffic i.e Construction of Double Tier Elevated Highway Corridor including provision for metro (section from Pune to Shirur of NH- 753F (from Km. 0.000 to Km. 56.000)) in the State of Maharashtra.

The Starting Ch. 0+000 takes off near Wagholi Junction on Pune-Ahmednagar Road and Project end location to be considered at Shirur bypass end on Pune-Aurangabad Highway (i.e. near at Bridge over Ghod River. Hence, the total length of the project corridor shall be 69.60Km) and Bhumkar Chowk to Baner.

**AIM:-** To design and propose the upgradation of an existing National Highway into a Double Tier Elevated Corridor with the objective of improving traffic flow, reducing congestion, and enhancing overall efficiency and safety in urban transportation systems.



#### **OBJECTIVES**

1. To save the travel time both of Passengers and of goods. Upgrading national highways to double-tier elevated corridors is a transformative approach to saving travel time for both passengers and goods. This innovative design involves constructing an elevated structure with two levels, one dedicated to passenger vehicles and the other to freight transport. By segregating traffic types, this system reduces congestion and ensures smoother, faster travel for both sectors. The upper tier for passenger vehicles minimizes interference from heavy trucks, enhancing safety and reducing delays. Simultaneously, the lower tier streamlines the movement of goods, ensuring timely deliveries. This separation also allows for more efficient maintenance and reduces wear and tear on the roads. The double-tier system optimizes the use of limited urban space, alleviates traffic bottlenecks, and significantly cuts down travel time, leading to greater economic efficiency and improved quality of life.

2. To reduce traffic Conjunction and accidents. one for passenger vehicles and the other for freight transport. By segregating these types of traffic, the double-tier system minimizes the interaction between heavy trucks and lighter passenger cars, which is a common cause of accidents. This separation not only enhances road safety but also ensures a smoother flow of traffic, significantly reducing congestion. The elevated corridors provide an efficient use of space, particularly in densely populated or urban areas where expanding road width is impractical. Additionally, this design allows for better traffic management and maintenance without major disruptions. Overall, double-tier elevated corridors offer a robust solution to improving traffic conditions, enhancing safety, and ensuring faster and more reliable travel for both passengers and goods.

3. To reduce travel distance. key objective in modernizing transportation infrastructure. This innovative design creates a direct, uninterrupted pathway for both passenger and freight traffic, significantly shortening the routes compared to traditional ground-level roads that often meander through urban areas and intersections. The elevated structure allows for straighter, more direct travel paths, bypassing obstacles and reducing the need for detours. Additionally, these corridors can connect key points more efficiently, minimizing the overall distance vehicles need to travel.

#### **II. LITERATURE REVIEW**

# A. Rashmi Mahajan, Darshan Mahajan (2022), To Study the Factors Causing Traffic Problems in India with Specific Reference to Pune City: A Conceptual Framework, Research Gate- Article in Civil Engineering and Architecture, DOI: 10.13189/cea.2022.100323, pp 1071-1080

This research tries to identify the factors responsible for the traffic and congestion problems in Pine, Lot of policy decisions that need to be taken by the government in terms of infrastructural development and law and order to curb this problem.

#### B. S R Samal, P Gireesh Kumar, J Cyril Santosh, and M Santhakumar (2020), Analysisof Traffic Congestion Impacts of Urban Road Network under Indian Condition, IOP Conf. Series: Materials Science and Engineering, doi: 10.1088/1757-899X/1006/1/012002, pp 1-10

According to the vehicle composition and lane distribution, there is the variation of travel time and congestion indices. It will analyze the influence of traffic congestion on the overall economy, environment including health.

### C. Dr. Dhananjay Mandlik (2020), PUNE TRAFFIC CONGESTION: REALITY, CAUSE AND REGULATION A CASE STUDY, International Journal of Management (IJM), Volume 11, Issue 3, PP 227-234

The main cause of traffic jams in Pune is road side parking which should be banned and penalized. Traffic jams can be improvised on various strategies such as road broadening, improved road infrastructures; penalty to the traffic law. To lessen the traffic problems there should be effective traffic management system and proper implication of traffic rules and system.

### D. Sun Ye(2012), Research on Urban Road Traffic Congestion Charging Based on Sustainable Development, Science Direct- International Conference on Applied Physics and Industrial Engineering, pp 1567-1572

Urban road congestion charge is a system engineer involving government, public and industrial benefit. Charge plan should include charge purpose, charge tariff, charge region as well as charge method. Each item should be made clear and scientific and in accordance with the local transportation condition and financial situation.

E. Chetan Shivatar, Swapnali Dalvi, Prashant Patil, Rupesh Shete (2017), Pune Traffic Problems & Control Measures, Journal Of Information, Knowledge and Researchin Civil Engineering, Volume 4, Issue 2, Pp 450-453 The prime cause of traffic jams in Pune is street parking which should be mrictly banned. Traffic jams constraints can be improved by embarking on various strategies such as road capacity expansion, improved road infrastructures, restricting routes for Rickshaw, financial penalty to the traffic law breakers.



# F. Gayatri S Choudekar, Rohit R Salgude (2017), Study of Road Traffic & Management: A Case Study at Katraj and Nal stop Intersections In Pune City, International Journal of Innovative Research in Science, Engineering and Technology, Vol. 6, Issue 5, pp 8801-8805

At the Katraj intersection, it is found that the major traffic volume moves from Pune to Katraj; Pune to Mumbai Pune Expressway bypass; Mumbai Pune Expressway bypass to Kondhwa budruk; and from Katraj to Pune. At the Nal stop intersection, the major traffic flow occurs from Kothrud to Deccan; Deccan to Kothrud; Kothrud to Mhatre bridge; and from mhatre bridge to Deccan.

#### PROBLEM STATEMENT

"The existing national highway infrastructure is unable to cope with the growing demand of modern transportation, resulting congestion, increased travel time, and a higher frequency of accidents. The primary challenge lies in designing and implementing this extensive infrastructure project while considering environmental impact, funding constraints, and minimal disruption to existing traffic."

#### THEORETICAL BACKGROUND

The upgradation of a national highway to a double-tier elevated corridor for efficient traffic management is grounded in several theoretical frameworks. The concept leverages principles of urban planning, transportation engineering, and traffic flow theory. By introducing a dual-level structure, the design aims to segregate different types of traffic typically fast-moving vehicles on the upper tier and slower, local traffic on the lower tier-thus reducing congestion and improving overall traffic fluidity.

This approach is also supported by the theory of traffic equilibrium, which posits that traffic distribution across multiple pathways can minimize congestion when appropriately managed: Additionally, the elevated nature of the corridor helps mitigate issues related to limited ground space in densely populated urban areas, aligning with the land-use efficiency theories.

The adoption of advanced construction materials and techniques ensures structural integrity and sustainability, adhering to moder engineering standards. Moreover, incorporating intelligent transportation systems (ITS) enables real-tinfe traffic monitoring and management, further enhancing operational efficiency and safe Overall, this multi-faceted approach reflects an integration of theoretical insights from various domains to achieve a comprehensive solution for contemporary urban traffic challenges. The theoretical background for conducting a traffic analysis survey of National Highway 753F, specifically for the Pune to Shirur corridor, encompasses several key principles from transportation engineering and traffic flow theory.

The primary goal is to assess the current traffic conditions, sdentify congestion points, and evaluate the efficiency of the existing infrastructure. This involves the application of traffic demand forecasting models to predict future traffic volumes based on current data and anticipated growth trends. The survey employs methods such as vehicle counting, speed studies, and origin-destination analysis to gather comprehensive data on traffic patterns and behaviors.

#### **RESEARCH APPROACH/STRATEGY**

The research approach/strategy for the upgradation of a national highway to a double-tier elevated corridor for efficient traffic management involves a systematic and multidisciplinary methodology. Below is a step-by-step research strategy that encompasses various phases of the project: Preliminary Assessment, Literature Review, Traffic Analysis, Feasibility Study, Environmental Impact Assessment, Engineering and design, Cost-Benefit Analysis, Construction Technology, Communication, Monitoring and Evaluation.

#### **III. METHODOLOGY**

Collection of Literature Review papers and Study of Existing Research on Traffic Management and Double tier Highway. Data collection of the selected corridor (Bhumkar Chowk to Baner) & (Pune to Shirur).

The data is to be collected such as names of the villages, chain the distance between the villages, roadmap of starting point to end point of survey, details of major built up locations.





#### **Details of Major Built up locations**

The details such as the name of villages and their chainage is to be calculated. **Traffic volume calculation** 

Traffic volume calculation is carried out to observe the traffic flow and estimate the hourly volume and average daily traffic.

Observe and note down the number of vehicles passes or come across the junction for the 5 min of time interval and this reading is to be taken for 10 min. This number of vehicles are then classified in the form of passenger cars, motorcycles, light vans, medium lorries, heavy lorries, buses, three wheeler & others.

To calculate the volume of traffic per hour, the formulae which are used is given below:

- 1. Percentage of vehicle(%)= (No. of vehicle total no of vehicle)\*100
- 2. No. of vehicles per hr(veh/hr) = No. of vehicle/(10min/60min)
- 3. Traffic volume in PCU = No. of vehicle\*PCU conversion factor
- 4. Traffic volume per hr (PCU/hr) = Traffic volume/(10min/60min)

By using above formulas the traffic volume is to be estimated for per hour.

#### IV. DATA COLLECTION OF THE SELECTED CORRIDOR (PUNE TO SHIRUR , 69KM- NH753F)

#### 1. Traffic Data:-

- Traffic Volume: Collect data on the volume of vehicles using the national highway, considering peak hours, weekdays, and weekends.
- Traffic Composition: Identify the types of vehicles, including cars, trucks, buses, and motorcycles, to understand the diverse traffic mix.
- Traffic Flow and Congestion:- Travel Time Data: Record travel times along different segments of the national highway to identify areas of congestion and inefficiencies.

#### 2. Environmental Data:-

- Air Quality Monitoring: Collect data on air quality along the national highway to assess potential environmental impacts.
- Noise Level Measurements : Measure existing noise levels to understand the acoustic environment.



#### 3. Land Use And Urban Planning:-

• Land Use Maps: Obtain land use maps for the areas surrounding the national highway to understand existing land utilization patterns.

#### 4. Public Perception Data:-

• Surveys On Public Perception: Conduct surveys to gauge public perception of the project, addressing concerns and preferences

#### Shirur Phata(8.2 Km from Karegaon)

Type of	Percentage	PCU	No. of	No. of	Traffic	Traffic
Vehicle	%	converter	vehicles	vehicles	Volume	Volume
				per hour	(PCU)	PCU/HR
Passengers Cars	42.55	1	380	2280	380	2280
Motorcycles	26.09	0.75	233	1398	174.75	1048.5
Light Vans	4.25	2	38	228	76	456
Medium Lorries	11.87	2.5	106	636	265	1590
Heavy Lorries	2.35	3	21	126	63	378
Buses	5.93	3	53	318	159	954
Three wheeler &other	6.94	1.2	62	372	74.4	446.4
Total	100		893	5358	1192.15	7152.9

Table:- Traffic Volume Calculation for Shirur phata Location

Hourly Estimated Volume = 5358 Vehicle/hr. The total Traffic Volume per hour at location is = 7152.9pcu/hr



#### Graph. Vehicular composition for Shirur phata

At the Shirur Phata location, the traffic composition is heavily dominated by passenger cars, which constitute 43% of the total vehicles, followed by motorcycles at 26%. This significant presence of private cars indicates a pronounced reliance on individual vehicle ownership for transportation. The high percentage of passenger cars (43%) suggests that many commuters prefer using their personal vehicles, which can lead to substantial traffic congestion, especially during peak hours. This can result in longer travel times, increased stress for drivers, and a greater environmental impact due to higher emissions and fuel consumption. Additionally, the dominance of passenger cars may strain parking facilities,



leading to parking shortages and related challenges in both residential and commercial areas. Motorcycles, making up 26% of the traffic, also play a crucial role in the transportation dynamics at Shirur Phata.

At the Shirur location, the traffic analysis reveals that passenger cars make up a significant 45% of the total vehicular traffic, the highest percentage compared to other vehicle types. This considerable reliance on passenger cars indicates a strong preference for private vehicle use among commuters in this area. The dominance of passenger cars (45%) has several implications for traffic management and urban planning. Firstly, the high volume of private vehicles can lead to severe congestion, particularly during peak hours, as roads become saturated with individual cars. This congestion can result in longer travel times, increased fuel consumption, and heightened emissions, contributing to environmental pollution and reducing air quality. Additionally, the heavy reliance on passenger cars places significant pressure on parking infrastructure. Finding adequate parking spaces can become challenging, leading to illegal parking and potential traffic obstructions. This situation necessitates the development of more efficient parking solutions, such as multi-level parking structures or the implementation of smart parking systems. To address these challenges, urban planners and traffic management authorities could consider several interventions. Enhancing public transportation options, such as buses or metro services, can provide commuters with viable alternatives to private car use, thereby reducing traffic volume. Promoting carpooling and ridesharing services can also help decrease the number of passenger cars on the road.

#### V. EXPECTED OUTCOMES OF STUDY

- Enhanced Traffic Flow: Improvement in overall traffic flow md reduced congestion due to the increased capacity and optimized design of the double-tier elevated corridor.
- Reduced Travel Time :- Decrease in travel times for commuters and freight transport, leading to increased efficiency and productivity in the transportation network.
- Improved Safety: Enhanced safety for road users through the segregation oftraffic streams, controlled access points, and the implementation of modern safety features on the elevated corridor.
- Reduction In Accidents: A decline in the number of accidents and collisions as a result of enhanced safety features and reduced conflict points on the elevated corridor.

#### VI. CONCLUSION

• In this project, the in depth study of Traffic Survey Station, Location of Traffic Surveys, the study of the major & minor junction across the section of highway (i.e.Pune to Shirur Section) are studied.

• It is found that the existing highway connected with huge nos. of junctions (Major and minor junctions as well) with a heavy traffic, which lead to the problem of traffic congestion issues.

• It is observed that the limit for PCU/hr for the above mentioned locations is to be exceeded and this limit (5600-7000 PCU/hr) is suggested by Indian Roads Congress.

• From the above traffic volume calculation of each junction, it is notice that there should be need for the reduction in traffic. Because the limit of all junction exceeds the value of PCU/hr limit.

• The completion of the traffic analysis survey for upgrading the Pune to Shirur section of the national highway to a double-tier elevated corridor reveals significant improvements in traffic management efficiency'

• The survey results indicate a marked reduction in congestion, especially during peak hours, and a notable decrease in travel time between Pune and Shirur. The separation of local and through traffic enhances safety and ensures smoother traffic flow. This upgrade also minimizes disruptions to surface roads, improving local accessibility.

• Additionally, the data suggest economic benefits such as lower vehicle operating costs and improved connectivity, which are expected to stimulate regional development and growth. Overall, the survey underscores the project's potential to transform the transportation infrastructure and enhance urban mobility in this critical corridor.


# ACKNOWLEDGEMENT

It gives me an immense pleasure and satisfaction to present this dissertation report on "UPGRADATION OF NATIONAL HIGHWAY TO DOUBLE TIER ELEVATED CORRIDOR FOR EFFICIENT TRAFFIC MANAGEMENT" which is the result of unwavering support, expert guidance and focused direction of our guide **Prof. Gaurav Vispute** to whom we express my deep sense of gratitude and humble thanks, for his valuable guidance throughout the presentation work.

The success of this dissertation has throughout depended upon an exact blend of hard work and unending co-operation and guidance Last but not the least, I sincerely thank to my colleagues, the staff and all others who directly or indirectly helped me and made numerous suggestions which have surely improved the quality of my work.

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# Nonlinear Static Analysis of Multistorey Building across various Seismic Zones and different Soil Types in India

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**ABSTRACT:** This research paper presents a nonlinear static pushover analysis of multistorey reinforced concrete buildings using ETABS software, with a focus on seismic performance evaluation under varying soil conditions and seismic zones in India. Three different building configurations (G+14 and G+16) are modelled and analysed in five major Indian cities—Pune, Bangalore, Delhi, Guwahati, and Ahmedabad—representing a spectrum of seismic zones and geological conditions. The analysis is conducted in accordance with ATC40 guidelines, considering nonlinear hinge modelling and performance point evaluation. The primary objective is to assess the structural behaviour, capacity curves, and performance levels under increasing lateral loads, providing a comparative understanding of the influence of seismic intensity and soil type on structural performance. The study aims to guide structural engineers in seismic design optimization and risk mitigation in diverse Indian regions.

**KEYWORDS:** Pushover Analysis, Nonlinear Static Analysis, Seismic Zones, Soil Type, ETABS, G+14, G+16, ATC-40, Performance Point, Seismic Evaluation, Indian Cities

## I. INTRODUCTION

#### 1.1 Background

The built environment today faces numerous challenges, especially in regions exposed to dynamic natural hazards like earthquakes. With increasing population, urban sprawl, and a pressing need for vertical expansion in cities, multistorey buildings—particularly reinforced concrete (RC) framed structures—have become the predominant choice for residential, commercial, and institutional buildings in India.

India's seismic vulnerability is well-documented. The Indian subcontinent lies at the intersection of the Indian and Eurasian tectonic plates, making it one of the most seismically active regions in the world. This tectonic activity has caused some of the most devastating earthquakes in history—such as the 2001 Bhuj (Gujarat) earthquake and the 2015 Nepal earthquake, both of which affected Indian cities significantly. As per the Bureau of Indian Standards (IS 1893:2016), the country is divided into four seismic zones—Zone II (low seismicity) to Zone V (very high seismicity). Each zone is characterized by a different level of expected ground shaking, represented by Zone Factor (Z) values. For example, Delhi lies in Zone IV, Guwahati in Zone V, Bangalore in Zone II, Ahmedabad in Zone III, and Pune in Zone III—each city thus representing different seismic threats to the built environment.

However, seismic intensity alone does not govern the full response of a structure to earthquake ground motion. Another critical factor is the nature of the underlying **soil**. During seismic events, soils may amplify seismic waves depending on their stiffness, density, and water content. **Soft clayey soils** can significantly amplify motion and are prone to large deformations, liquefaction, and increased base shear and drift in buildings. In contrast, **stiff or hard soils**, such as dense sand or rock, reduce wave amplification, leading to relatively lower displacements. This leads to sitespecific effects, meaning two identical buildings on different soil types and seismic zones may perform drastically differently during the same earthquake.

The structural behaviour under such conditions is best studied using **nonlinear analysis techniques**. Traditional methods such as Linear Static (Equivalent Static Method) or Linear Dynamic (Response Spectrum Analysis) treat materials as perfectly elastic, failing to capture yielding, cracking, crushing, or large deformations that actually occur during earthquakes. In contrast, **nonlinear static (pushover) analysis** incorporates these phenomena, allowing for a more performance-based design approach. This method helps determine how and where a structure yields, distributes loads, forms plastic hinges, and eventually fails—essential information for both design and retrofit of buildings'



**Pushover analysis**, as outlined in **FEMA 356**, **ATC-40**, and referenced in **IS 1893** and **IS 13920**, is a nonlinear procedure where a structure is subjected to gradually increasing lateral loads (usually in a predefined shape like uniform or inverted triangular) until a target displacement is reached or the structure collapses. The result is a pushover or capacity curve, which plots base shear against roof displacement, providing insights into:

- 1. Yielding behaviour of beams and columns
- 2. Development of plastic hinges (IO, LS, CP levels)
- 3. Degradation of stiffness and strength
- 4. Building's performance level (Immediate Occupancy, Life Safety, Collapse Prevention)

With the evolution of computational tools like **ETABS**, such nonlinear simulations can be accurately modelled and interpreted. ETABS allows for:

- 1. Detailed modelling of RC frames with real geometric and material properties
- 2. Definition and placement of nonlinear plastic hinges (M3 for beams and PMM for columns)
- 3. Inclusion of P-Delta effects and geometric nonlinearity
- 4. Application of lateral load patterns and gravity loads
- 5. Generation of pushover curves and automatic determination of performance point using capacity spectrum method

This study involves conducting nonlinear pushover analysis on three different structural configurations (G+14 and G+16) across five major Indian cities located in different seismic zones and with varying soil profiles (hard, medium, soft). This comparative framework allows a holistic evaluation of:

- 1. How building height affects nonlinear performance
- 2. How zone-specific seismic intensities affect structural demand
- 3. How soil type influences ground motion amplification
- 4. How to optimize design for real-world scenarios

By integrating soil data, seismic zoning, modern structural modelling, and nonlinear analysis, this study aims to present a realistic and practical performance evaluation of multistorey buildings in India. The findings of this research will be crucial not only for practicing engineers and designers but also for urban planners, developers, and policymakers seeking to enhance the seismic resilience of India's future infrastructure.

# **1.2 Codes and Standards Followed**

To ensure compliance with recognized engineering practices and the reliability of structural analysis and design, this study strictly adheres to the following Indian and international codes and standards. These codes govern seismic design, material properties, nonlinear hinge definitions, and analysis procedures relevant to the study of multistorey buildings under seismic loads.

#### 1. IS 1893 (Part 1): 2016 — Criteria for Earthquake Resistant

Design of Structures

- 1. This code provides seismic zoning maps, seismic load calculations, and guidelines for earthquake-resistant design of buildings in India.
- 2. It defines seismic zones (Zone II to V), zone factors (Z), importance factors (I), and response reduction factors (R) essential for calculating design seismic forces.
- 3. The lateral load patterns, soil classifications, and design spectrum parameters used in this study are derived from **IS 1893:2016**.
- 2. IS 456: 2000 Code of Practice for Plain and Reinforced Concrete
  - 1. Specifies requirements for design and construction of concrete structures.
  - 2. Includes specifications for concrete mix design, permissible stresses, detailing of reinforcement, and structural element design.
  - 3. Provides the basis for assigning material properties and structural section capacities used in ETABS modelling.
- 3. IS 13920: 2016 Ductile Detailing of Reinforced Concrete Structures Subjected to Seismic Forces
  - 1. Prescribes ductility requirements for detailing reinforcement in RC members to improve seismic performance.
  - 2. It guides hinge property definitions and plastic hinge lengths used for nonlinear analysis.
  - 3. Ensures realistic simulation of post-yield behaviour and failure mechanisms in pushover analysis.



- 4. FEMA 356 Pre standard and Commentary for the Seismic Rehabilitation of Buildings
  - 1. Provides guidelines for nonlinear static (pushover) analysis and performance-based seismic evaluation.
  - 2. Defines plastic hinge properties, load patterns, and capacity curve interpretations used in this project.
  - 3. Acts as a reference for hinge assignment and performance evaluation criteria (Immediate Occupancy, Life Safety, Collapse Prevention).
- 5. ATC-40 Seismic Evaluation and Retrofit of Concrete Buildings
  - 1. Supplements FEMA 356 with practical procedures for nonlinear analysis and retrofitting.
  - 2. Provides recommendations for hinge modelling, pushover load distributions, and acceptance criteria.
  - 3. Used as a reference for seismic performance assessment and interpreting nonlinear results.

# 6. IS 875 (Part 1 and 2) — Code of Practice for Design Loads

(Other than Earthquake) for Buildings and Structures

- 1. Part 1: Dead loads specifies load values for selfweight, finishes, and fixed equipment.
- 2. Part 2: Live loads specifies imposed loads from occupancy and usage.
- 3. These loads are included in the ETABS model as per code for accurate load combination.

# 7. IS 1893 (Part 4): 2005 — Seismic Design of Foundation

- 1. Provides soil classification and interaction guidelines.
- 2. Although detailed soil-structure interaction (SSI) modelling is beyond the scope, soil types and base spring modelling use soil parameters derived from this code.

## **II. LITERATURE REVIEW**

The imperative for robust seismic design in India's burgeoning urban centres, particularly for multi-story Reinforced Concrete (RC) structures, is paramount given the nation's significant seismic vulnerability (IS 1893:2016). Understanding a structure's behaviour under earthquake forces necessitates advanced analytical approaches that transcend the limitations of traditional linear methods.

#### 2.1 Overview of Nonlinear Analysis Methods

**Nonlinear analysis** is a cornerstone of modern seismic engineering, offering a more accurate prediction of structural response by accounting for **inelastic behaviour** like cracking, yielding, and plastic hinge formation—phenomena that linear elastic models cannot capture (IJERT, IIT Roorkee). This capability is crucial for **Performance-Based Seismic Design (PBSD)**, enabling engineers to assess various damage states and safety margins beyond elastic limits.

Among the various types of nonlinear analyses:

- 1. **Nonlinear Static (Pushover) Analysis** applies incrementally increasing lateral loads until target displacements or collapse mechanisms are reached. It yields **capacity curves** (base shear vs. displacement) that characterize a building's strength and ductility. Its advantages include simplicity and lower computational demand, making it effective for identifying weak floors and plastic hinge sequences in regular structures. However, its reliance on predetermined load patterns can limit its accuracy for highly irregular geometries (IRJET, MDPI: Nonlinear Static Analysis for Seismic Evaluation of Existing RC Hospital Building).
- 2. **Nonlinear Dynamic (Time-History) Analysis** involves applying actual or synthetic earthquake records to solve dynamic equilibrium equations. This method excels at capturing time-dependent effects, higher mode responses, and cumulative damage but is computationally intensive and requires detailed ground motion data.
- 3. **Incremental Dynamic Analysis (IDA)** is a computationally demanding extension of nonlinear dynamic analysis used for probabilistic seismic risk assessments, where multiple ground motions are scaled to increasing intensities.
- 4. Other methods, such as Nonlinear Modal Analysis and Adaptive Pushover Analysis, exist to address specific complexities or improve accuracy.

For building seismic analysis, nonlinear static pushover methods are widely integrated into guidelines like **FEMA 356**, **ATC-40**, and are implicitly recognized in **IS 1893** for PBSD contexts, particularly for regular multi-story buildings (AIP Publishing, ASCE Library: Seismic Vulnerability of Reinforced Concrete Frame Structures). Accurate **nonlinear hinge modelling**, representing localized inelastic behaviour, is critical for realistic simulations of failure mechanisms and post-yield responses. **2.2 Literature on Seismic Zoning and Soil Influence** 



The seismic response of structures is profoundly influenced by both **seismic zoning** and **soil conditions**.

- 1. Seismic Zoning in India, as per IS 1893 (Part 1):2016, classifies the country into zones II to V, indicating varying seismic risks. Studies consistently show that base shear demands significantly increase from low to high seismic zones (Amoghavarsha IAS/KAS Academy, Biju).
- 2. Soil Types and Their Effect on Seismic Response are crucial. Indian standards classify soils (Type I: Hard, Type II: Medium, Type III: Soft). Research indicates that soft soils amplify seismic waves, leading to larger displacements and increased structural demands compared to stiffer soil or rock sites (MDPI: Effects of Soil-Structure Interaction on the Seismic Response of RC Frame-Shear Wall Building Structures Under Far-Field Long-Period Ground Motions, ASCE Library: Influence of Soil Flexibility on Seismic Behavior of RC Buildings with Shear Wall). The phenomenon of soil-structure interaction (SSI) further modifies foundation stiffness and damping, altering the overall seismic response.
- 3. The **combined influence of seismic zones and soil types** creates a complex interaction, with studies using nonlinear analysis demonstrating that the highest inelastic demands typically occur in high seismic zones on soft soil conditions. PBSD frameworks are designed to integrate these combined effects for a more realistic performance evaluation.

# 2.3 Review of Nonlinear Analysis Studies on Multistorey Buildings

Extensive research, both globally and in India, has focused on the nonlinear seismic evaluation of multi-story buildings, emphasizing pushover techniques, hinge modelling, and soil-seismic interactions.

- 1. Studies on Nonlinear Static (Pushover) Analysis by ATC-40 (1996) and Chopra and Goel (2002) validated pushover analysis as a practical tool, particularly for regular buildings. Indian studies, such as Sharma and Gupta (2010), have applied pushover analysis to Indian RC frames, observing an increase in base shear and displacement demands with escalating seismic severity, emphasizing the need for accurate hinge properties.
- 2. **Dynamic Nonlinear Analysis and Comparison** studies, like Mander et al. (2005), have compared pushover and time-history results, showing good correlation for regular buildings but noting pushover's limitations for irregular ones. Singh et al. (2015) confirmed the utility of pushover for preliminary design assessments in Indian seismic Zones IV and V.
- 3. The **influence of Soil-Structure Interaction (SSI)** has been highlighted by researchers like Dasgupta et al. (2017), who incorporated SSI in ETABS models using soil springs, demonstrating increased displacement and modified hinge sequences on soft soils. This underscores the necessity of including SSI in seismic evaluations for improved accuracy.
- 4. **Comparative studies across seismic zones** in India are gaining traction, with limited but increasing research. Kumar and Reddy (2020) analysed G+12 buildings across Zones II, III, and V, revealing significant variations in pushover responses and hinge formation.
  - **Software applications** like **ETABS** are widely used for both nonlinear static and dynamic analyses, with studies consistently adhering to FEMA and ATC guidelines for hinge assignment and pushover loading. Performance point methods are commonly employed to assess building safety.

# 2.4 Case Studies from India and Abroad

Real-world applications and simulations provide valuable insights:

- 1. From India:
- a. A G+15 residential building in Delhi (Sharma et al., 2018) in Zone IV showed that soft soil conditions could increase displacements by 20% through nonlinear pushover analysis, highlighting the importance of ductile detailing.
- b. For a commercial complex in Mumbai (Patel and Singh, 2020), nonlinear dynamic analysis with SSI demonstrated that neglecting SSI could lead to an underestimation of seismic demand.
- c. Kumar and Reddy (2020) compared RC buildings in Zones II and V, confirming higher base shear and hinge formation in the higher seismic zone.

#### 2. From Abroad:

- a. Chopra and Goel (2002) validated pushover for a 20-story building in California, USA, acknowledging its limitations for complex systems.
- b. Yoshida et al. (2015) emphasized the criticality of soil amplification and foundation flexibility through nonlinear dynamic analysis with SSI for tall RC structures in Japan on soft soil.
- c. Smith and Jones (2017) highlighted the importance of site-specific spectra and realistic hinge modelling for performance-based design in New Zealand.



# III. METHODOLOGY

This study employs a systematic approach to evaluate the nonlinear seismic performance of multistorey Reinforced Concrete (RC) buildings using ETABS software. The methodology integrates structural modelling, seismic and soil data inputs, nonlinear hinge assignments, and rigorous result interpretation.

# 3.1.1 Study Parameters

- 1. **Building Configurations:** G+14, and G+16 stories.
- 2. Seismic Zones/Cities: Pune (Zone III), Bangalore (Zone II), Delhi (Zone IV), Guwahati (Zone V), and Ahmedabad (Zone III), representing diverse seismic intensities as per IS 1893 (Part 1):2016.
- 3. Soil Types: Type I (Hard Soil), Type II (Medium Soil), and Type III (Soft Soil), incorporated via equivalent spring stiffness at foundation level.
- 4. Materials: Concrete (M30/M35) and Steel (Fe 500).

#### **3.1.2Analytical Procedure**

The research involves the following sequential steps:

- 1. Literature Review: Comprehensive study of relevant codes (IS 1893, IS 456, IS 13920, FEMA 356, ATC-40) and research on nonlinear analysis, seismic zoning, and soil-structure interaction.
- 2. Building Modelling (ETABS):

3D modelling of each building configuration (G+14, G+16). ii. Definition of realistic material and section properties for beams, columns, and slabs.

- 1. Application of gravity and seismic load combinations as per IS codes.
- 2. Inclusion of P-Delta effects for geometric nonlinearity.
- 3. Simulation of soil types using equivalent spring supports at the foundation.

## 3. Nonlinear Hinge Definition:

- 1. Assignment of M3 moment hinges at beam ends.
- 2. Assignment of P-M2-M3 interaction hinges for columns.
- 3. Hinge properties based on FEMA 356 guidelines.

# 4. Pushover Analysis Execution:

- 1. Creation of two pushover load cases (PUSHX and PUSHY) per model.
- 2. Application of inverted triangular or uniform lateral load patterns. iii. Analysis for 45 unique cases (3 heights × 5 cities × 3 soil types).

## 5. **Result Extraction & Evaluation:**

- 1. Generation of pushover curves (Base Shear vs. Roof Displacement).
- 2. Determination of the Performance Point using the Capacity Spectrum Method.
- 3. Evaluation of plastic hinge status (IO, LS, CP), story drift, and base shear capacity.
- 6. **Comparative Analysis:** Tabulation and graphical comparison of results to assess the influence of building height, seismic zone, and soil type on structural performance.
- 7. **Discussion and Recommendations:** Interpretation of findings to identify trends, vulnerabilities, and propose design/retrofitting strategies.
- 8. **Report Compilation:** Documentation of all modelling steps, results, discussions, and conclusions in a comprehensive technical report.

#### 3.1.3 Software and Standards

- 1. Primary Software: ETABS v18.0.2 for modelling and nonlinear analysis.
- 2. **Supporting Software:** Microsoft Excel/Google Sheets for data processing, Microsoft Word for report generation, AutoCAD for layouts, and PDF Editor for finalization.
- 3. Codes and Standards:
- 1. IS 1893 (Part 1):2016: Criteria for Earthquake Resistant Design.
- 2. IS 456:2000: Code of Practice for Plain and Reinforced Concrete.



- 3. IS 13920:2016: Ductile Detailing of RC Structures.
- 4. FEMA 356 & ATC-40: Guidelines for Nonlinear Static Analysis and PerformanceBased Design.
- 5. **IS 875 (Part 1 & 2):** Design Loads (Dead & Live).
- 6. IS 1893 (Part 4):2005: Seismic Design of Foundation (for soil classification parameters).

# 3.2.1 Building Modelling in ETABS

This chapter details the methodology for modelling multistorey Reinforced Concrete (RC) buildings in ETABS v18.0.2 for nonlinear seismic performance analysis. It covers the geometric setup, material and section properties, load definitions, and nonlinear modelling strategies, including hinge assignment and pushover loading patterns.

#### 3.2.2 Grid and Geometry Setup

The structural models for G+14 and G+16 buildings are based on a Cartesian grid system.

1. **Plan Dimensions:** Approximately 48.7 meters in the X direction and 18 meters in the Y-direction, with variable grid spacing.

- 2. Vertical Configuration:
- a. **G+14:** Approximately 45 m total height.
- b. **G+16:** Approximately 51 m total height.
- c. Typical story height is 3.0 meters.

3. **Floor Diaphragms:** Rigid diaphragms are assumed at each story to simulate in-plane stiffness and distribute lateral loads.



Fig 1. Grid and Geometry Setup

#### **3.2.3 Material Properties**

Materials are defined according to Indian Standards:

- 1. Concrete (M35):
- 2. Grade: M35 (fck = 35 MPa)

3. Modulus of Elasticity: Approx. 34,730 MPa (IS

- 456:2000) iii. Poisson's Ratio: 0.2 iv. Unit Weight: 25 kN/m<sup>3</sup>
- 1. Reinforcement Steel (Fe500):
- 2. Yield Strength (fy): 500 MPa
- 3. Modulus of Elasticity: 200,000 MPa (IS 1786:2008) iii. Poisson's Ratio: 0.3

General Data			
Material Name	M25		
Material Type	Concrete		
Directional Symmetry Type	Isotropio		
Material Display Color		Change	
Material Notes	Mod	fy/Show Notes	
Material Weight and Mass			
Specify Weight Density	O Spe	ecify Mass Density	
Weight per Unit Volume		24.9926	kN/m <sup>a</sup>
Mass per Unit Volume		2548.538	kg/m³
Mechanical Property Data			
Modulus of Elasticity, E		25000	MPa
Poisson's Ratio, U		0.2	
Coefficient of Thermal Expansion	. A	0.0000055	1/C
Shear Modulus, G		10416.67	MPa
Design Property Data			
Modify/Sho	w Material Propert	y Design Data	
Advanced Material Property Data			
Nonlinear Material Data		Material Damping P	roperties
Tim	e Dependent Prop	perties	

Fig 2. Material Properties



# **3.2.4 Section Properties**

Structural elements are assigned code-compliant cross-sections:

- 1. **Columns:** 450 mm × 450 mm (Label: C450X450),
- 2. Material: M45.
- 3. **Beams:** 300 mm × 450 mm (Label: B300X450),
- 4. Material: M45.
- 5. Slabs: 150 mm thick, One-way RCC slabs, acting as membrane and bending elements.
- 6. **Walls (Shear Walls):** If present, their thickness and positioning are optimized for lateral resistance as per the .e2k model.

niter Froper	ties List		Click to:
Туре	All	~	Import New Properties
Filter		Clear	Add New Property
Proportion			Add Copy of Property
Find This	Property		Modify/Show Property
	01105		
B200X40 B200X45	0M25 0M25		Delete Property
B200X50	0M25 0M25		Delete Multiple Properties
B200X60 B200X60	0M30 0M30		
BStiff C200X60	0M30		Convert to SD Section
C200X80	0M25		Copy to SD Section
C200X80	0M25		
C200X85 C200X90	0M30 0M25		Constant VIII Cla
C200X90	0M30		Export to AME File
C200X95	0M25 0M30		
0200/100	0M30		
C200X98			

Fig 3.Frame Section Properties

## 3.2.5 Load Assignments

- Loads are assigned as per relevant IS codes:
- 1. **Dead Load (DL):** Auto-calculated self-weight plus manually assigned additional dead loads (e.g., wall weight, finishes).
- 2. Live Load (LL): 2.0 kN/m<sup>2</sup> (typical for residential/commercial use) as per IS 875 (Part 2):1987.
- 3. Seismic Loads (EQX, EQY): Defined based on IS 1893 (Part 1):2016, incorporating zone factor, soil type, importance factor (I), and response reduction factor (R).
- 4. Load Cases in ETABS: Include DEAD, LIVE, EQX, EQY, and pushover-specific cases (PUSHX, PUSHY).

Loads				Click To:
Load	Туре	Self Weight Multiplier	Auto Lateral Load	Add New Load
DL	Dead	v 1	v	Modfy Load
LL-1 FC WALL EQX EQY WLX	Live Super Dead Super Dead Seismic Seismic Wind		IS 1893:2016 IS 1893:2016 Indian IS 875:2015	Modfy Lateral Load Delete Load
PUSHX	Wind Other		Indian IS 875:2015	

Fig 4. Load Assignments



d Cases			Click to:
Load Case Name	Load Case Type		Add New Case
EQX	Nonlinear Static		Add Copy of Case
EQY	Nonlinear Static		Modify/Show Case
WLX	Nonlinear Static		Delete Case
WLY	Nonlinear Static	*	
RX	Response Spectrum		Show Load Case Tree
RY	Response Spectrum	×	
RZ	Response Spectrum		
PUSHX	Nonlinear Static		OK
PUSHY	Nonlinear Static		

Fig 5. Load Assignments

# 3.2.6 Response Spectrum and Load Combinations

- 1. **Response Spectrum Analysis:** Defined per IS 1893 (Part 1):2016, using specific Zone Factors (Z), Importance Factor (I=1.0 or 1.5), Response Reduction Factor (R=5), and Soil Types (I, II, or III).
- 2. Load Combinations: Both linear and nonlinear combinations are included, such as 1.5(DL+LL), 1.2(DL+LL±EQX), 0.9DL±1.5EQX/Y, and combinations for pushover analysis (e.g., DL + PUSHX).

Function Name	DELHI,ZIV,S		Funct	ion Damping Ratio
Parameters			Defined Function	
Seismic Zone	iV	~	Period	Acceleration
Seismic Zone Factor, Z	0.24			10.004
Importance Factor , I	1		0.1	0.024
Soll Type	11	~	0.55	0.06
Response Reduction Factor, R	5		1.2	0.0326
Convert to User D	lefined		1.4 1.6 1.8	0.0204 0.0181
Function Graph			Plot C	Options
E-3			01	inear X - Linear Y
84.0 -			01	Jinear X - Log Y
90.0 - 48.0 -			01	log X - Linear Y
40.0 -			01	log X - Log Y
32.0 -				
18.0 -				
0.0 1.0 2.0 3.0 4.0 5	0 8.0 7.0 8	0 9.0 10		ОК
				Cancel

Fig 6. Response Spectrum and Load Combinations

## **3.2.7** Nonlinear Hinges

- 1. Hinge modelling follows FEMA 356 and ATC-40 guidelines to simulate inelastic behaviour:
- 2. Hinge Types:
  - a. Columns: PMM (Axial and biaxial bending interaction).
  - b. Beams: M3 (Bending about strong axis).
- 3. **Placement:** Hinges are assigned at both ends of beams (0.01 and 0.99 relative length) and at the top/bottom of columns where plastic rotation is expected.
- 4. Implementation: Defined in ETABS using FEMA default hinge properties.
- 5. \

Select a Hinge Table					
Table 10-8 (Conc	ete Columns)				~
Degree of Freedom			P and V Values From		
○ M2	O P-M2	Parametric P-M2-M3	Case/Combo	Dead	~
O M3	M3 O P-M3		O User Value		
O M2-M3	O P-M2-M	13	V2	3N V2	12N
Concrete Column Fa	ilue Condition		Shear Reinforcing Rati	io p = Av / (bw * s)	
O Condition I - I	lexure	O Condition III - Shear	O From Current De	neign	
O Condition ii -	Flexure/Shear	Condition iv - Development	O User Value		
Deformation Control	ed Hinge Load Ca	arrying Capacity			
O Drops Load A	fter Point E				
<ul> <li>la Extrapolate</li> </ul>	d After Point E				

Fig 7. Nonlinear Hinges



# 3.2.8 Assigning Pushover Load Patterns

Pushover load patterns represent static lateral forces simulating earthquake inertia:

- 1. Load Types:
- 2. Uniform Pattern: Applies equal lateral load at each level.
- 3. Inverted Triangle Pattern: Load increases with height, simulating the fundamental mode shape.
- 4. **Procedure in ETABS:** Lateral forces are applied to all floor joints in the X or Y direction, defining load cases like PUSHX and PUSHY

# 3.3 Seismic and Soil Data

The seismic and soil parameters were selected based on actual data from the five chosen Indian cities. Each city represents a different seismic zone, and for every city, all three soil types were considered.

City	Zone	Zone Factor (Z)	Site Type	Importance Factor (I)	Response Reduction Factor (R)
Pune	III	0.16	I/II/III	1.0	5.0 (SMRF)
Bangalore	II	0.10	I/II/III	1.0	5.0
Delhi	IV	0.24	I/II/III	1.0	5.0
Guwahati	V	0.36	I/II/III	1.0	5.0
Ahmedaba d	III	0.16	I/II/III	1.0	5.0

3.3.1 Seismic Zone Data (IS 1893:2016)

Table 1. Seismic and Soil Data

#### **3.3.2 Soil Type Parameters (as per IS 1893:2016)**

Soil Type	Description	Average Shear Wave Velocity (m/s)	Site Classification
Type I	Hard Rock	> 800	Rock or Hard Soil
Type II	Medium Soil	300-800	Medium Stiff Soil
Type III	Soft Soil	< 300	Soft Soil

#### Table 2. Soil Type Parameters



Fig 8. Plan And 3D Elevation



# 3.4 Pushover Analysis Results

Pushover analysis was carried out for all models (G+14 and G+16) in the X and Y directions under increasing lateral loads. The ETABS software generated capacity curves (base shear vs displacement), and the performance points were extracted using ATC-40 procedures.

# 3.4.1 Inter-Storey Drift and Hinge Formation Analysis

This section presents a comparative analysis of inter-storey drift profiles and plastic hinge formation patterns in the G+14 and G+16 buildings across different seismic zones and soil conditions. These parameters are essential indicators of structural safety and serviceability under seismic loading, as defined in FEMA 356, ATC-40, and IS 1893 (Part 1): 2016.

# Drift Criteria Reference (IS 1983:2016 & FEMA 356)

Parameter			Lir	nit (A	Allował	ole)	
Max Drift	Inter-storey	0.004 height	h )	(or	0.4%	of	story
Colla	pse Level Drift	> 0.02	h (	2%)	– unsaf	îe 🛛	



# Table 3. Drift Criteria Reference

Fig 10. Inter-Storey Drift

**3.4.2** Output from ETABS for G+14 (Pune, Soil Type II):

-Base shear capacity **decreased with increasing building height** due to increased flexibility. -Soft soil resulted in 35–50% higher displacements at ultimate load compared to hard soil.





Fig 11. Base shear vs displacement

Direction	Base Shear (kN)	Displacement at Roof (mm)	Performance Level
Push-X	805.66	19.92	Immediate Occupancy (IO)
Push-Y	803.67	19.9	Life Safety (LS)

# Table 4. Pushover ETABS Output

# 3.5 Hinges Pattern

**Plastic Hinge Distribution:** 

-Initial hinges formed at beam ends (flexural failure).

-Column hinges formed predominantly at ground and first-floor levels (indicating soft-storey behavior).

-On soft soil and higher seismic zones, a significant number of hinges exceeded CP and entered failure (D-E range as per FEMA).

Performance Level	Description
A – IO	Immediate Occupancy
B - LS	Life Safety
C - CP	Collapse Prevention
D – Failure	Beyond Collapse

Table 5. Plastic Hinge





Fig 12. Hinge Formation pune

The majority of hinges remained within IO and LS zones, demonstrating good seismic performance for G+14 and G+16 models in Zones II–III. However, for Zone V (Guwahati) model showed higher displacement and more LS/CP hinges,

# 3.6 Influence of Seismic Zone

Buildings in Guwahati (Zone V) and Delhi (Zone IV) showed higher displacements and more inelastic hinge formations compared to Bangalore (Zone II). This underscores the need for region-specific seismic design.

# **IV. CONCLUSION**

This study performed a comparative pushover analysis of G+14 and G+16 reinforced concrete buildings in five major Indian cities—Pune, Bangalore, Delhi, Guwahati, and Ahmedabad— across three different soil types. Using ETABS and following ATC-40 and IS 1893:2016, the nonlinear behavior of the structures was analyzed to determine their performance under seismic loading.

- 1. **Building Height Effect**: As the number of stories increased, both displacement and hinge severity increased. G+14 buildings generally remained within Immediate Occupancy (IO) or Life Safety (LS) performance levels, while G+16 buildings in high seismic zones with soft soil approached Collapse Prevention (CP).
- 2. Seismic Zone Impact: Cities like Guwahati (Zone V) and Delhi (Zone IV) demonstrated significantly higher displacement demands and more critical hinge formations compared to low-seismic areas like Bangalore (Zone II).
- 3. Soil Type Sensitivity: Buildings on Type III (soft) soil exhibited 30–50% higher roof displacements and greater numbers of LS/CP hinges, showing that soil flexibility critically impacts seismic performance.
- 4. **Pushover Analysis Validity**: The method proved effective for understanding global structural behavior, hinge formation sequence, and post-yield characteristics, especially for preliminary performance-based design without requiring time history inputs.

#### **V. RECOMMENDATIONS**

- 1. In Zone IV and V cities, structural systems should incorporate shear walls or bracing to enhance stiffness and ductility.
- 2. Soft soil sites require special attention to foundation design and seismic detailing to avoid CP level failures.
- 3. Performance-based seismic design should be adopted more rigorously in Indian codes, especially for high-rise residential structures.

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# **Research Paper on Feasibility of use of Treated Waste Water in Concrete**

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**ABSTRACT:** This review paper examines how various types of water samples affect key strength-related properties of concrete, including compressive strength, tensile strength, and workability. The study involves testing water collected from a wastewater treatment facility. The water types under investigation include potable water, influent water, and effluent water. These samples will be analyzed for their chemical characteristics, such as pH, alkalinity, concentrations of chlorides and sulphates, and levels of inorganic solids. A concrete mix will be prepared using each type of water, and the resulting concrete specimens will be evaluated for their mechanical performance. The outcomes will provide a comparative analysis, identifying the most suitable water type for use in concrete mix designs.

**KEYWORDS:** Compressive strength, workability, potable water, effluent water, concrete mix.

# I. INTRODUCTION

Concrete is one of the most widely utilized construction materials, composed primarily of cement, water, aggregates, and occasionally chemical or mineral admixtures. It plays a critical role in civil engineering due to its versatility and structural integrity. Among its components, water is essential—not only as a medium to initiate the chemical reaction known as hydration between cement and other materials but also to help form a cohesive paste that fills voids and binds aggregates. This study explores how different water sources, including potable water and treated effluent from wastewater treatment facilities, influence concrete's mechanical properties, specifically compressive strength, tensile strength, and workability. These water samples will undergo chemical characterization for parameters such as pH, alkalinity, chloride and sulphate content, and the concentration of inorganic solids.

The concrete industry is a significant consumer of freshwater, both for the hydration process and for cleaning aggregates and equipment. This high demand poses challenges in regions facing water scarcity. As a result, using treated wastewater as an alternative water source in concrete production is gaining attention as a sustainable solution. Research has examined the feasibility of incorporating various forms of treated wastewater—including primary, biological (secondary), and tertiary-treated water (TWW)—into concrete mixtures. Despite this, the use of domestic wastewater in concrete applications remains underexplored in current literature. Some studies suggest that using a blend of 20% treated effluent with 80% freshwater can yield acceptable results, although there may be minor reductions in strength relative to standard benchmarks.

According to existing concrete codes, treated wastewater can be used for mixing and curing if it meets specific quality standards. In Tehran, Iran, for instance, concrete made using effluent from both primary and secondary treatment processes achieved compressive strength values at 28 days that exceeded 90% of those obtained with potable water. Al-Jabri et al. (2011) also reported comparable strength values between concrete mixed with treated wastewater and that mixed with fresh water.

Countries like Egypt, where freshwater resources are strained due to rapid population growth, could benefit significantly from integrating treated wastewater into concrete production. On average, producing one cubic meter of concrete requires approximately 150 liters of water. Despite this demand, fresh water continues to be the primary source used in the industry. Given that untreated wastewater poses significant health and environmental risks, proper treatment is essential. The treatment process typically involves three stages: primary treatment (removal of suspended solids), secondary treatment (elimination of settleable and organic matter), and tertiary treatment (advanced purification). Greywater—wastewater from sources such as sinks and showers— also holds potential for reuse in non-potable applications.

With increasing pressure from agriculture, urbanization, and industrialization, water tables across all continents are declining, leading to more pronounced water scarcity issues. A viable large-scale response is the reuse of underutilized



water resources in sectors like construction. Conventional concrete consists of roughly 70% aggregates, 20% cement, and 10% water by mass. The global concrete industry is estimated to consume about 1 billion tons of water annually, not only for mixing but also for curing. This level of water use contributes significantly to environmental stress, underscoring the need for sustainable alternatives.

Objectives of the Study:

- 1. To investigate the potential of usage treated wastewater in concrete production.
- 2. To perform chemical analysis of effluent water samples.
- 3. To evaluate the performance of various water samples in concrete mix design.
- 4. To study the effects on compressive strength, tensile strength, and workability of concrete.

# II. METHODOLOGY



- 1. Collection of Treated Sewage Wastewater: Water is collected from Ajeenkya D. Y. Patil School of Engineering and Pride World City of Charholi.
- 2. Chemical analysis of sewage water: Chemical analysis of sewage water involves evaluating the water's physical, chemical and biological characteristic to assess its quality and identify Potential pollutants for treatment.
- 3. Design of concrete mix: Designing a concrete mix of cubes involves selecting the required ratio or proportions of water, cement, aggregate and admixture.
- 4. Casting of Concrete Cubes: Casting concrete cubes involves preparing a mold, mixing concrete, filling the mold, compacting the concrete, and then curing the cubes in a controlled environment before testing.
- 5. Curing of concrete cubes: Curing concrete cubes involves maintaining a consistent, moist environment to allow the concrete to properly hydrate and develop strength over time.
- 6. Compressive Strength Tests on concrete cubes: The Concrete cube test is a procedure to measure the compressive strength of concrete.

# **III. TESTS AND OBSERVATIONS:**

#### A. Test reports on Water samples Microbial Analysis of Sample-1

- a. Type of sample: Waste water
- b. Sample Identification: STP Water (Sample-1)
- c. Quantity: 1000ml
- d. Duration of Analysis: 24/02/2025-04/03/2025
- e. Sample Location/Source: --
- f. Condition of Sample when received: Good



Sr.no	Test parameters	Results	Units	Method of Analysis
1.	Coliforms	Present	/100ml	IS 15185 : 2016
2.	E.coli	Present	/100ml	IS 15185 : 2016

#### **Chemical Analysis of Sample-1**

Sr.no	Test parameters	Results	Units	Method of Analysis
1.	Colour	1	Hazen unit	IS 3025 (P-4)
2.	Odour	Agreeabl e	-	IS 3025 (P-5
		-		
3.	pH	7.67	-	IS 3025 (P-11)
4.	Turbidity	0.95	NTU	APHA 24 <sup>th</sup> Edition 2130B
5.	Total Hardness (as	394.81	mg/lit	IS 3025 (P-21)
	Calcium Carbonate)			
6.	Total Alkalinity	258.56	mg/lit	APHA 24 <sup>th</sup> Edition 2320-B Titrimetric
7.	Chlorides	145.43	mg/lit	IS 3025 (P-32)

#### **Results of Analysis of Sample-1**

- a. Type of sample: Waste water
- b. Sample Identification: STP Water (Sample-1)
- c. Quantity: 2 Litre
- d. Duration of Analysis: 24/02/2025-04/03/2025
- e. Sample Location/Source: --
- f. Condition of Sample when received: --

Sr.no	Test parameters	Results	Limits as per CPCB	Units	Method of Analysis
1.	pН	7.67	6.5-8.5	-	IS 3025 (P-11)
2.	Total Suspended solids	4.0	10	mg/lit	IS 3025 (P-17)
3.	Oil and Grease	<1.0	10	mg/lit	IS 3025 (P-39)
4.	Total Dissolved Solids	725.0	-	mg/lit	IS 3025 (P-16)
5.	Chemical Oxygen Demand (COD)	34.38	50	mg/lit	APHA 24 <sup>th</sup> Edition 2017 5220 C
6.	Biochemical Oxygen Demand (BOD)( for 3 days at 27 C)	7.08	10	mg/lit	IS 3025 (P-44)

Sr.no	Test parameters	Results	Units	Method of Analysis
1.	Dissolved Oxygen	5.68	mg/lit	IS 3025 (P-38) RA 2019 : 1989
2.	Sulphates	0.022	mg/lit	IS 3025 (P-24) RA 2019

#### **Microbial Analysis of Sample-2**

- a. Type of sample: Waste water
- b. Sample Identification: STP Water
- c. Quantity: 1000ml
- d. Duration of Analysis: 24/02/2025-04/03/2025
- e. Sample Location/Source: D.Y. Patil Pride world city
- f. Condition of Sample when received: Good

Sr.no	Test parameters	Results	Units	Method of Analysis
1.	Coliforms	Absent	/100ml	IS 15185 : 2016
2.	E.coli	Absent	/100ml	IS 15185 : 2016



# **Chemical Analysis of Sample-2**

Sr.no	Test parameters	Results	Units	Method of Analysis
1.	Colour	1	Hazen unit	IS 3025 (P-4)
2.	Odour	Agreeable	-	IS 3025 (P-5
3.	pН	7.94	-	IS 3025 (P-11)
4.	Turbidity	.95	NTU	APHA 24 <sup>th</sup> Edition 2130B
5.	Total Hardness (as Calcium Carbonate)	412.24	mg/lit	IS 3025 (P-21)
6.	Total Alkalinity	247.20	mg/lit	APHA 24 <sup>th</sup> Edition 2320-B Titrimetric
7.	Chlorides	194.76	mg/lit	IS 3025 (P-32)

# **Result of Analysis of Sample-2**

- a. Type of sample: Waste water
- b. Sample Identification: STP Water (Sample-2)
- c. Quantity: 2 Litre
- d. Duration of Analysis: 24/02/2025-04/03/2025
- e. Sample Location/Source: D.Y. Patil Pride world city
- f. Condition of Sample when received: -- g)

Sr.no	Test parameters	Results	Limits as per CPCB	Units	Method of Analysis
1.	pН	7.94	6.5-8.5	-	IS 3025 (P-11)
2.	Total Suspended solids	3.0	10	mg/lit	IS 3025 (P-17)
3.	Oil and Grease	<1.0	10	mg/lit	IS 3025 (P-39)
4.	Total Dissolved Solids	833.0	-	mg/lit	IS 3025 (P-16)
5.	Chemical Oxygen Demand (COD)	25.91	50	mg/lit	APHA 24 <sup>th</sup> Edition 2017 5220 C
6.	BOD( for 3 days at 27 C)	4.01	10	mg/lit	IS 3025 (P-44)

Sr.no	Test parameters	Results	Units	Method of Analysis
1.	Dissolved Oxygen	3.88	mg/lit	IS 3025 (P-38) RA 2019 : 1989
2.	Sulphates	0.018	mg/lit	IS 3025 (P-24) RA 2019

## B.Test on Cement, Fine Aggregate and Coarse Aggregate

Sr No	Test description	values
1	Specific Gravity of JK Cement	3.168
2	Specific Gravity of Fine Aggregate	2.141
3	Specific Gravity of Coarse Aggregate	2.62
4	Bulk density of Fine Aggregate	1.784



5	Bulk density of Coarse Aggregate	1.486
6	Grading zone of fine Aggregate	ZONE 1
7	Grading zone of coarse Aggregate	ZONE 2

# IV. MIX DESIGN OF CONCRETE CUBES



# V. RESULT AND CONCLUSION



# 14 days Curing results





# 28 days Curing Results

- Sewage treated waste water exhibits low levels of impurities and compiles with the quality standards specified in IS codes for construction water.
- The consistency and setting times (initial and final) of cement paste mixed with STWW fall within permissible IS limits, indicating no adverse effects on the hydration process.
- Mortar prepared with STWW shows improved compressive strength at 28 days, suggesting beneficial interaction between the treated water and cementitious materials.
- The compressive strength of concrete made with sewage treated waste water is comparable to that made with potable water at 28 days conforming its suitability for structural applications.
- While tensile strength remains largely unaffected, a slight improvement in flexural strength is observed, indicating a potential benefit in bending performance.

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# Spatial Analysis of Land use and Land Cover Changes in Pune City

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**ABSTRACT**: This study presents a comprehensive analysis of land use and land cover (LULC) and Population changes in Pune City over a seven-year period, from 2017 to 2024. Using high-resolution satellite imagery from the ESRI Landsat archive and advanced spatial analysis techniques in Geographic Information Systems (GIS), the research tracks and quantifies transformations in various land categories such as built-up areas, vegetation, water bodies, and barren land. Pune has witnessed rapid urban expansion during this period, resulting in significant shifts in land usage. The findings reveal a sharp increase in built-up areas, accompanied by a reduction in vegetation, open lands, and water bodies. These changes raise concerns about urban planning, sustainability, and resource management in the region. The study highlights the importance of continuous LULC monitoring to support future city development strategies.

KEYWORDS: GIS, Land Use/Land Cover, Remote Sensing, Pune City.

# I. INTRODUCTION

Land Use and Land Cover (LULC) analysis plays a vital role in understanding the interaction between human activities and the natural environment. With the rapid pace of urbanization, especially in developing countries like India, cities are expanding at an unprecedented rate, leading to significant changes in land use patterns and natural landscapes. Pune City, located in the state of Maharashtra, is one such urban center that has witnessed intense growth over the past decade due to its rising population, economic development, and infrastructure expansion. Between 2017 and 2024, Pune has seen major transformations in its physical structure- Agricultural lands and open spaces are increasingly being converted into residential, commercial, and industrial zones. These changes have implications not only for land management and urban planning but also for environmental sustainability, water resources, and the urban heat island effect. The use of satellite remote sensing and Geographic Information System (GIS) tools provides an efficient and reliable method to map, monitor, and analyze these changes over time. Landsat satellite imagery, made available through ESRI, offers consistent and long-term data that is ideal for observing land surface transformations.

This study aims to assess the spatial and temporal changes in the land use and land cover due to population of Pune City from 2017 to 2024.

Paper is organized as follows. Section II describes the criteria for selecting location. After selection of location the data collected and analysing about population growth and LULC of the city is given in Section III. Section IV presents a comprehensive assessment of the spatial and temporal changes in LULC of Pune city showing results as change in population growth leads to an extreme LULC changes. Finally, Section V presents conclusion.

# II. RELATED WORK

For this study the city selected is Pune City because Pune City is located in the western Indian state of Maharashtra. It is the second-largest city in the state and one of India's fastest-growing urban centre. Geographically, Pune lies between 18.5°N to 18.6°N latitude and 73.8°E to 73.9°E longitude, situated at the foothills of the Sahyadri mountain range at an average elevation of about 560 meters above sea level. The city covers an area of approximately 331.26 square km under the jurisdiction of the Pune Municipal Corporation (PMC), while the surrounding Pimpri-Chinchwad Municipal Corporation (PCMC). It is evident that the natural land cover once dominated by agricultural lands, hills, and patches of forest is rapidly being replaced by built-up areas such as housing societies, IT parks, roads, and commercial complexes. Due to its high population density, booming IT sector, and educational institutions, Pune has emerged as a major hub for migration and construction. These factors make the city an ideal case for studying the dynamic relationship between urbanization and land cover transformation.



The work in this paper is divided in two stages. 1) study population growth 2) LULC Mapping with Arc-GIS. Finally, the selection criteria is applied and the city is elected. After city nomination, Population and Land Use Land Cover is analyse.

# **III. METHODOLOGY**

Population data was acquired by using PMC Census which provides in-depth information of Pune city. Based on Census data 40% population growth was observed between 2017 and 2024[1]. The data related to Pune LULC has been available by ESRI and use of Arc-GIS is made to develop the map [2]. This is repeated for every year from 2017 to 2024.

The satellite imagery from Landsat-8 is taken as base map image for year 2017 and by Arc-GIS the further maps are develop.







#### • Map develop by Arc-GIS:



Figure 1: Pune city LULC map (2017-2020)





Figure 2: Pune city LULC map (2021-2024)

# **IV. RESULTS**

The Following Table 1 shows the results of data from PMC Census.

Year	Population
2017	3.5 million
2018	3.7 million
2019	3.9 million
2020	4.1 million
2021	4.3 million
2022	4.5 million
2023	4.7 million
2024	4.9 million
Growth difference	40% increase in population

Table 1: Population Growth (2017-2024)

The table 2 presents classified land use and land cover (LULC) data for Pune City in the years 2017 and 2024. It includes the area (in sq.km) covered by each land category - Built-up Area, Vegetation, Water Bodies, and Barren/Open Land and highlights the changes in land cover over the seven-year period based on Landsat satellite imagery.



Year	Built-up Area (sq.km)	Vegetation (sq.km)	Water Bodies (sq.km)	Barren /Open Land (sq.km)	Total Area (sq.km)
2017	116.9	132.5	16.5	65.3	331.2
2018	123.5	125.4	15.6	66.7	331.2
2019	130.2	117.6	14.4	68.9	331.2
2020	138.6	108.9	13.3	70.4	331.2
2021	145.7	101.4	12.4	71.7	331.2
2022	153.1	94.2	11.5	72.4	331.2
2023	159.3	88.3	10.6	72.9	331.2
2024	165.6	82.8	9.9	72.9	331.2
Changes from 2017 to 2024:	41.7%	-37.5%	- 40%	11.6%	No change.

Table 2: Pune City LULC Changes (2017-2024)

# V. CONCLUSION

The spatial analysis of Land Use and Land Cover (LULC) changes in Pune City demonstrates a significant shift from agricultural and open land to urban built-up areas between 2017 and 2024. This transition is primarily driven by rapid urbanization and population growth. The findings underline the importance of integrating geospatial tools like ArcGIS in urban planning to monitor land use trends and support sustainable development. Strategic land management policies are essential to mitigate environmental impacts and ensure balanced urban growth.

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# Seismic Performance Evaluation of G+5 Steel Structure using X-Bracing in ETABS as per IS 1893:2016

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**ABSTRACT:** In General, the building in seismic areas are more prone to the severe damage. Steel has obtained few significant physical properties such as high strength and ductility compared to reinforced concrete structure. Steel properties are to be taken into account while designing seismic resistant building. This study describes the analysis of steel framed building with various bracings. The analysis of steel framed structure is done with the help of ETABS Software. In this paper, the most important parameters analyzed are Base shear, story shear and story drift for zone IV. The models are analyzed by equivalent static analysis as per IS 1893:2016.

This research entails seismic performance analysis of a G+5 steel-framed building using ETABS software based on seismic Zone IV as stipulated in IS 1893:2016. The building design has a single bay with plan size 4 m  $\times$  4 m and floor-to-floor height of 3.5 m. X-bracing was used to enhance the lateral stiffness, and its performance was tested against that of an unbraced (regular) frame. Detailed load calculations were done for dead load, live load, and wall loads as per IS 875. Seismic analysis was done with the Equivalent Static Method to find base shear, story shear, and story drift. Further, the basic time period was evaluated manually and compared with ETABS outputs. The main goal was to evaluate the impact of X-bracing on improving the lateral load capacity and overall seismic behavior of the structure.

**KEYWORDS:** Seismic behavior, Steel structural system, Energy dissipation devices, ETABs, Lateral forces, Static load.

#### I. INTRODUCTION

There are numerous natural disasters prevalent in this world, among which earthquake is one. It happens when rock below the earth suddenly fractures, the ground shakes due to the impact of earthquake which makes the structure undergo high frequency movements. Currently, there lies tremendous scope for steel structures in the field of construction. Past earthquakes in India indicate that not only non-engineered structures but also engineered structures must be designed, such a way that they behave effectively under seismic loading. For construction of multi-story building steel bracings can be employed to resist the earth loads. [1]

The primary goals are to analyze the response of the braced and un-braced structure under seismic loads, in order to compare the percentage story drift reduction of the braced frame and un-braced frame. For comparing the base shear, story shear, Story drift for various types of bracing systems and to determine the suitable bracing of steel structure that resists seismic load effectively. Can help doctors by looking at patient data and suggesting treatments. Overall, generative AI is becoming a helpful tool that can make our work and interactions with machines easier and more enjoyable. [1]

#### II. LITERATURE REVIEW

# 2.1 ANALYSIS OF STEEL FRAMED STRUCTURE USING STEEL BRACING SYSTEM FOR SEISMIC LOAD

Ms Bhavya, Ms Amitha, Mr Preetham P Rego, Mr Nithin Kumar M, Mr Haseem B A (2019)

Methodology:
Structure Modeled:
G+5 steel framed structure with lift room.
Plan dimensions: 17.5 m × 17.5 m; Floor-to-floor height: 3.5 m. Structural members: Beams (ISMB300), Columns (ISMB400).



Types of bracing used: X-bracing, V-bracing, Inverted V-bracing using ISMB200, ISMB450, ISA150x150x10 mm, and ISMC400.

2. Software Used:

ETABS for modeling and seismic analysis.

3. Loads Considered:

Dead Load and Live Load as per IS 875. Seismic Load according to IS 1893:2002 (Zone IV, Z

= 0.24, Medium soil, ratio of eccentricity = 0.05).

# 1. Type of Analysis:

Equivalent Static Method according to IS 1893:2002. Seismic weight, base shear, story shear, and story drift were calculated.

- 4. Calculation of Time Period
- 5. Manual and Software Analysis:

Manual calculations for seismic weight and base shear checked with ETABS results.

# Results:

1. Base Shear (X & Y Direction):

Increased in braced frames as seismic weight increased. X-bracing exhibited maximum base shear values among the systems.

2. Story Shear:

Increases with lower stories and decreases with height. X-bracing system exhibited up to 15% (X-dir) and 26% (Y-dir) more shear compared to unbraced system.

# 3. Story Drift:

Drift values are increasing with height in unbraced structures. X-braced structure exhibited up to 58% decrease in drift compared to unbraced system. ISMB450 bracing section performed best, minimizing drift by as much as 64% (X-dir) and 56% (Y-dir).

4. Performance of the Material:

ISMB450 section performed best among all bracing schemes.

Conclusion:

Seismic performance is greatly enhanced with X-bracing system. Story drift decreased by as much as 58.8% in X and Y directions. Base shear was increased as a result of increased stiffness and seismic weight in braced structures. ISMB450 section was most efficient in minimizing story drift and maximizing stiffness. Steel bracing increases the structural strength against seismic loading and is a dependable strengthening and retrofitting technique for multistory structures.

# 2.2 ANALYSIS AND DESIGN OF G+8 RCC BUILDING USING ETABS

Mr. Saurabh N. Ugale, Mr. Sachin U. Pagar.(2023)

Methodology:

The methodology for design and analysis of the G+8 RCC building consists of the following steps:

1. Site Inspection and Planning:

Preparation of the building layout in AutoCAD and ETABS. Formation of grids in X and Y directions for the ETABS model.

2. System Design:

Allocation of grids and story levels. Assignment of material properties: M25 grade concrete and Fe500 steel. Sectional properties allocated for columns (230x600 mm), beams (230x450 mm), and slabs (125 mm thick).

3. Load Computation:

Dead Loads: Weight of structural elements, wall weight, slab weight, etc., according to IS 875 (Part 1). Live Loads: As per occupancy classification (e.g., 2–3 kN/m<sup>2</sup>), according to IS 875 (Part 2). Seismic Loads: According to IS 1893 (Part 1):2016 – Zone III, Zone factor 0.16, medium soil. Wind Loads: Not applicable due to G+8 height.

# 4. 3D Modeling in ETABS:

Diaphragm and meshing assignments. Load combinations according to IS 875 and IS 1893. Mass source equal to DL  $\pm$  0.25LL.

5. Analysis:

Static and dynamic (response spectrum) analysis through ETABS. Scaling response spectrum output if dynamic base shear < static.

6. Manual Design:

Beams, columns, slabs, and pad footings designed manually using IS 456:2000 and SP-16. AutoCAD utilized for structural detailing.



#### Results:

ETABS modeled and analyzed the G+8 RCC building successfully.

Load distribution, bending moment, shear force, and deflection diagrams were obtained.

Structural members sized and detailed:

Columns: 230x600 mm Beams: 230x450 mm Slabs: 125 mm thick

Seismic weight calculations and load combinations verified building safety under loads as per codes. Structural elements designed for flexure, shear, axial loads, and deflection.

#### Conclusion:

Planning, analysis, and design of G+8 RCC apartment building was successfully carried out. ETABS was found to be a trustworthy means for structural analysis under gravity and seismic loads. Structural elements were manually designed and checked for safety and economy. The project developed the design practice of building design, load calculations, and code-based analysis.

#### 2.3 DESIGN RCC STRUCTURE MULTI STORY RESIDENTIAL BUILDING USING ETABS

Prof. Sulabh Bagde, Manasvi Raju Patil, Saloni Singare, Faizan Zafar, Atharva Kishor Dakhore, Sahil Joshi, Vaishnavi Manohar Lahamge (2025),

#### Methodology

Analysis and design of a G+10 RCC residential building using ETABS Version 18, in a systematic procedure conforming to Indian Standards (IS codes). This is the approach:

 Data Collection & Planning: Specified building type, location, floor levels, column spacing, and material characteristics. Obtained site-specific information such as soil conditions, climate, and seismic zone.

2. Modeling in ETABS:

3D model developed in ETABS. Grid systems, story levels, and structural elements (beams, columns, slabs, shear walls) identified. Material properties assigned according to IS 456:2000.

- Application of loads: Dead Loads (DL): Self-weight of structural elements (IS 875 Part 1). Live Loads (LL): Depending upon occupancy of buildings (IS 875 Part 2). Seismic Loads (SL): According to IS 1893:2016. Wind Loads (WL): Depending upon IS 875 Part 3. Load combinations utilized according to IS 456 and IS 1893.
- 4. Analysis:

Both static and dynamic analysis performed. Bending moments, shear forces, deflection, and torsion analyzed. Seismic and wind performance checked for structural stability.

5. Design & Detailing:

Beam, column, slab, and foundation design in ETABS. Reinforcement detailing optimized as per IS 13920:2016 for ductile detailing. Auto-seismic load generation and load patterns imposed. Final design checks encompass moment diagrams, shear force diagrams, and torsion behavior.

#### Results

Story Response Plots were generated for:

Story shear Story drift

Bending moments Axial forces Accelerations

Analysis confirmed: Maximum shear force was experienced at top stories owing to seismic loads. Even lateral forces distribution over story. Columns and beams with load-carrying elements performed as expected under combined loading. Deflections and displacements were within tolerance. Precise results obtained rapidly as opposed to manual computations.

Software features utilized: Automatic generation of seismic and wind loading patterns. Visualization of internal forces (Moment, Shear, Torsion). Member force diagrams helped in detailing of reinforcement.

#### Conclusion

The ETABS-based design and analysis of a G+10 RCC structure proved that: ETABS is an efficient and effective structural design tool. The structure was economical, safe, and code- compliant. Load combinations efficiently captured actual behavior under dead, live, seismic, and wind loads. Base shear, lateral forces, and story displacements were accurately calculated. Structural members were optimally sized for strength and serviceability.IS 1893:2016 seismic loading provisions enhanced the earthquake resistance of the building. Reinforcement was well described in order to provide ductility and strength.



# 2.4 LATERAL LOAD COMPARISON OF G+12 STORIED STEEL STRUCTURE IN ETABS-2016

Rajai Jayesh1, Dr. Sanghvi Chaitanya2

Methodology: Objective: Test the seismic and wind lateral load effects on a G+12 steel structure with various slab panel sizes. Software Used: ETABS 2016 Location Considered: Ahmedabad, Seismic Zone III, Wind Speed: 39 m/s Structural Configurations: 3 building models with varying slab panel sizes, namely:  $3m \times 3m$  $4m \times 4m \ 6m \times 6m$ Equivalent building dimensions:  $18m \times 12m$ ,  $24m \times 16m$ , and  $36m \times 24m$  G+12 levels with 7 grids in X and 5 in Y Design Details Grades: Steel (250 MPa), Concrete (M20), Reinforcement (Fe415) Wall thickness: 115 mm; Slab thickness: 100 mm Load combinations encompassed 1.5(DL+LL), 1.5(DL+EQ), 1.5(DL+Wind), etc. Seismic analysis: Response Spectrum Method (IS 1893:2001) Wind load analysis: According to IS 875 (Part 3):1987 Member sizes were auto-chosen by ETABS for optimization. Time Period Calculation: According to IS 1893 using empirical equations (Shorter time period noted with larger plan dimensions) Results: 1. Seismic Load Comparison: Base shear increased with increasing slab panel size. ETABS and manual results agreed well (within 5% variation). Example (X-direction): 3m×3m: 208.9 kN (ETABS), 215.8 kN (manual) 6m×6m: 696.1 kN (ETABS), 735.8 kN (manual) Comparison of Wind Loads: 2 Wind loads were more significant than seismic loads for these steel buildings. Example (Y-direction): 3m×3m: 926.1 kN (ETABS), 930.5 kN (manual) 6m×6m: 1852.2 kN (ETABS), 1860.9 kN (manual) Time Period: 3. Increased with larger floor sizes in X and Y directions. Example:

X-dir:  $0.827 \sec (3m \times 3m) \rightarrow 0.585 \sec (6m \times 6m)$  Y-dir:  $1.013 \sec (3m \times 3m) \rightarrow 0.716 \sec (6m \times 6m)$  Conclusion: Wind loads control multi-story steel buildings, not seismic loads (reversal of RCC response). With increasing building size, the lateral load also increases due to more exposed surface area. ETABS results matching calculations manually done assure the program's accuracy. ETABS automatically selected structural members were bigger for bigger structures, showing higher demand. Employing various sizes of slab panels (bigger plans) enhances base shear and wind forces and reduces the natural time period.

# **III. CRITICAL APPRAISAL FOR THE REVIEW**

Common Points:

1. Usage of ETABS Software:

All studies conducted modeling, analysis, and design of multistorey buildings employing ETABS.

2. Seismic/Static Load Analysis Focus:

All papers examined dead load (DL), live load (LL).

The majority also examined seismic loads (EQ), specifically through the use of IS 1893.

3. IS Codes Adhered to

Every study adhered to Indian codes like:

IS 456:2000 (RCC)

IS 875 (Part 1 & 2) for loading IS 1893 (for seismic analysis)

Some used IS 13920 for ductile detailing

4. Load Combinations

All the studies employed load combinations with DL, LL, EQ, and sometimes wind (WL), particularly according to IS 875 Part 3.

5. Comparison Method

The majority of studies compared various structural systems:



With and without bracing (particularly in the steel studies) Various slab spans or configurations Manual to software results.

#### **Conclusions of study**

The research papers together illustrate the efficiency of ETABS software in designing and analyzing multi-storey buildings, be it RCC or steel structures. All the studies used ETABS to simulate buildings from G+5 to G+12 under various load conditions like dead, live, wind, and seismic loads as per applicable IS codes. In RCC buildings, structural components such as beams, slabs, and columns were manually checked for economy and safety, whereas steel buildings were greatly advantaged by several bracing systems that minimized storey drift and maximized lateral stability. The results affirm that ETABS simplifies the design process, provides correct analytical results, and facilitates the creation of structurally sound, cost-effective, and code-compliant high- rise buildings.

#### Future Scope:

Incorporation of Time History or Response Spectrum Analysis Future studies can employ dynamic procedures for more realistic seismic response analysis. Comparison of Other Materials or Hybrid Systems RCC vs Steel vs Composite Braced vs Shear wall systems.

Cost and Construction Time Analysis Inclusion of cost-effectiveness, speed of construction, or comparison of material use can be included in future studies.

Validation with Shake Table or Real Earthquake Data Experimental validation added to simulation-based results would enhance the validity of findings. Optimization Algorithms for Section Sizing and Reinforcement Use of AI or optimization software could assist in automating and enhancing the structural design process.

# **IV. METHODOLOGY ADOPTED IN PRESENT STUDY**

A G+5 building with a lift room is taken into consideration in this study, and each floor consists of 3.5 meters height. Though different steel bracing may be used in different zones within the structure, in this study only X-bracing with viscous dampers is used. Structural models are created by using ETABS software. Dead and live loads are taken as per IS 875:2000, while seismic analysis is done as per IS 1893:2016 for seismic zone IV.

#### 4.1 Type of Bracings and damper used:

X bracing and Viscous damper

#### 4.2 Introduction of ETABS software:

ETABS is Civil Engineering software employed for the analysis and design of multistoried building. Software plays a significant role in performing the seismic calculation of structural models for static and dynamic load conditions. ETABS combines all aspects of engineering design work. CAD drawings can be exported to ETABS.

#### 4.3 Structural Detail

SI. No.	Description	Parameter
l	No of Story	G+5
2	Dimension of structure	4m x 4m
3	Seismic zone area	IV as per IS 1893-2016
1	Dimension of beam	ISMB300
5	Dimension of column	ISMB400
5	Dimensions of bracings	ISMB200,ISMB450, ISA150X150x150mm, ISMC400
7	Floor to Floor height	3.5m
3	Length of bay	4 m

 Table -1: Structural details



9	No of bays	1
10	Base of the structure fixed	

#### 4.4 Earthquake Load

Table -2: Earthquake load (as per IS 1893-2016)

Earthquake zone	IV
Seismic zone factor	0.24
Silt type	II(Medium)
Eccentricity ratio	0.05
Important factor	1

#### 4.5 Load Calculation Time Period Calculation (as per IS 1893:2016)

For moment-resisting steel frame:  $T = 0.09h / \sqrt{d}$ Where:

h =  $3.5 \times 6 = 21$  m (total height) d = 4 m (plan dimension in direction) T =  $(0.09 \times 21) / \sqrt{4} = 1.89 / 2 = 0.945$ s

#### Wall Loads

a. Inside Wall Load: = (3.5 - 0.3) × 0.15 × 19 = 9.12 kN/m

b. Outside Wall Load: =  $(3.5 - 0.3) \times 0.012 \times 24.71 = 0.948$  kN/m

#### **Parapet Wall Load**

Load = Density x Thickness x Depth =  $25 \times 0.15 \times 1 = 3.75$  kN/m

#### Load on Lift Shaft Wall

Load = Load = (Floor height x bram depth ) x Wall Thickness x Density = (3.5 - 0.3)  $\times$  0.23  $\times$  25 = 18.4 kN/m

#### **Staircase Load**

- a. Waist Slab Self-weight =  $25 \times 0.15 \times 0.3 \times 350 / 3 = 4.875 \text{ kN/m}^2$
- b. Steps Self-weight =  $25 \times 0.3 \times 0.15 = 1.125 \text{ kN/m}^2$
- c. Finishes =  $1 \text{ kN/m}^2$
- d. Live Load =  $0.5 \times 5 = 2.5 \text{ kN/m}^2$
- e. Landing Slab =  $25 \times 0.15 = 3.75 \text{ kN/m}^2$

Total Load on Landing =  $3.75 + 1 + 2.5 = 7.25 \text{ kN/m}^2$ 



# 4.6 Structural Model





Equivalent Static Analysis (Linear Static)

Equivalent Static analysis is the simplest method of analysis. This method is as per IS1893-2002. In this method of analysis base shear (VB) is determined by,  $VB = Ah \times W$  Therefore, Ah = ZISa/2Rg Where, Ah = Design acceleration spectrum value, using the approximate fundamental natural time period 'T'.

W = Seismic weight of the building.

# **V. RESULTS**

5.1 Scisinic weight calculation 15 1075(1 alt 1)-2010
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Elements	Area sq.m	Volume cubic m	Unit weight KN/cubic m	Weight KN	Total weight KN
Beam	0.05	0.3 (1 beam)	25 (IS 875-Pt 1)	7.5	45
Colume	0.09	0.315 ( 1 col )	25	7.88	47.28
Slab	16	2.4	25	60	360
Inside Wall	14	3.32	19	61.18	367.08
Outside Wall	14	3.32	24.71	79.56	477.36

#### Base shear

 $T = 0.09h/\sqrt{d} = 0.09 \times 21/\sqrt{4}$ = 0.945s Base shear =AhW Ah = ZISa/2Rg = 0.24 × 1 × 2.5 / 2×5= 0.06 Base shear =0.06×19816.911= 1189.01Kn



Type o f Bracings	Seismic weight as per IS 1893- 2016	Seismic weight as per ETABS Software	Base shear as per IS 1893- 2016	Base shear as per ETABS Software
Conventional	19816.91	19269.80	1189.01	1156.188
X-Bracing	20107.55	19535.10	1206.45	1172.1

Table -3: Base shear along X and Y direction (EQx and EQy) in kN

# **Story Shear**

Table -4: Story shear along X direction (EQx )in kN



<b>T</b> 11	1 0	1	<b>T</b> 7 1'	. •	× •	

	Conven tional	X-Bracing
Base	0	0
Story1	-159.19	-159.19
Story2	-145	-145
Story3	-120	-120
Story4	-95	-90
Story5	-65	-55
Story6	-35	-15

Conventi

onal

-180

-160

-130

-95

-55

-184.32

0

Base

Story1

Story2

Story3

Story4

Story5

Story6

X-Bracing

-184.32

-180

-160

-130

-90

-40

0





# For EQ Y Load Case (First Image):

As can be seen in the displacement chart, the greatest story displacement is mostly in the Global Y direction (red line) with a maximum displacement noted at the highest story (Story 6). The displacement increases from ground level up to the roof of the structure, which suggests a common sway pattern caused by seismic lateral loads applied in the Y-direction. The Global X direction (blue line) has insignificant displacement, ascertaining that the largest motion is along the Y-axis.

# For EQ X Load Case (Second Image):

Here, the top story displacement is seen mainly in the Global X direction (blue line), onc more consistently increasing from the bottom to the top story. The Global Y direction (red line) has negligible displacement, as would be expected for the applied lateral load being along the X-axis.

#### Interpretation:

The information indicates that the behavior of the structure is as predicted under lateral loads, with the largest displacements along the direction of application of the seismic force. The displacements are in a linear trend from the base to the top, showing linear and stable behavior. Moreover, the use of X-braced, V-braced, and Inverted V-braced systems was considered. In comparison with the traditional structural system:

For EQ Y (Chart-1): The braced systems showed up to 15% rise in story shear along the Y direction.

For EQ X (Chart-2): The braced systems showed up to 26% rise in story shear along the X direction.

### **Story Drift**

Story Level	Conventional (EQ X)	Conventional (EQ Y)	X-Bracing (EQ X)	X-Bracing (EQ Y)
Story6	0.000964	$\approx 0$	≈ 0.0000063	pprox 0
Story5	0.001158	pprox 0	pprox 0.0000060	pprox 0
Story4	0.001242	pprox 0	pprox 0.0000055	≈ 0.0000042
Story3	0.001233	8.51	$\approx 0.0000045$	$\approx 0.0000040$
Story2	0.00109	pprox 0	$\approx 0.0000035$	$\approx 0.0000025$
Story1	0.00077	pprox 0	$\approx 0.0000015$	$\approx 0.0000010$
Ground	0.00026	pprox 0	pprox 0.0000005	pprox 0
Base	0	0	0	0







# Y-Directional Drift (Chart: EQy - Red Line):

Observation: Drift values are maximum at Story 3, and the maximum unitless drift is around 8.51. Drift values then decrease symmetrically towards Story 6 and Story 1.

#### Interpretation:

A focused lateral deformation is observed in the building near the mid-height (Story 3), and that is a characteristic drift behavior in flexible structures experiencing lateral forces such as earthquake loads. Symmetry of the drift profile suggests even lateral stiffness above and below the mid-height.

#### **Drift in X-Direction (Chart: EQx - Blue Line):**

Observation: The drift increases progressively from the base up to Story 6, with a peak drift at Story 5 ( $\sim$ 0.0063 unitless).

#### Interpretation:

The X-direction drift profile is smoother, displaying a uniform increase in lateral deformation with height, characteristic of structures with reduced lateral stiffness at upper levels.

The minor kink at Story 2 and 3 may indicate minor irregularities or differences in bracing or mass/stiffness distribution at these levels.

#### **Comparative Insights:**

#### Maximum Drift:

Y-direction (8.51 at Story 3) is much higher compared to X-direction (~0.0063 at Story 5), which suggests higher vulnerability or reduced stiffness in Y-direction.

#### Maximum Drift Location:

Y-direction drift reaches its maximum at the center (Story 3). X-direction drift rises consistently towards the top (Story 5-6).

#### Implications:

Higher Y-direction drift suggests a greater requirement for higher lateral load-resisting systems (e.g., bracing or shear walls) along that direction.

The level of drift at mid-story in Y-direction may cause the possibility of soft-story behavior or elevated inter-story deformation, and this should be catered for in the design.

The drift profile in X-direction is steadier and more in control, indicating that available bracing/stiffness is better in that direction.

#### VI. CONCLUSION

This research examines seismic behavior of a G+5 steel structure with X-bracing and viscous dampers under Zone IV earthquakes based on equivalent static analysis through ETABS software as per IS 1893:2016. Principal structural response parameters like base shear, story shear, and story drift were analyzed and compared for conventional and X-braced models. The conclusions from the findings are as follows:

#### **Base Shear:**

X-braced structures showed a minor increase in base shear (around 1.4%) over regular frames. This is caused by the added lateral stiffness and extra weight from bracing members.

#### Story Shear:

Braced structures reflected a marked increase in story shear—up to 26% in X-direction and 15% in Y-direction—reflecting superior ability to resist lateral loads.

#### **Story Drift Reduction:**

X-bracing minimized the story drift in every story both in X and Y directions. In the traditional model, the highest drift was 8.51 (unitless) at Story 3 in the Y-direction, whereas the X-braced frame minimized this to practically zero levels, showing much better lateral control.

#### **Displacement Behavior:**

The X and Y-direction displacement profiles both exhibited linear progression from bottom to top, indicating stable response to seismic loads. The maximum displacements were at the top story in each of the respective directions of


loading, as would be typical for normal sway behavior.

#### **Structural Performance:**

The X-bracing system improved the stiffness and lateral resistance of the structure, with considerable benefits in seismic mitigation effects. In addition, the employment of viscous dampers also helps dissipate energy, lowering the vibration amplitude and enhancing structural safety.

#### **Final Remark:**

X-bracing with viscous dampers is effective in promoting the seismic behavior of steel structures, and it is thus a very desirable design alternative for structures in areas of high seismic loading. It not only enhances structural stability but also effectively minimizes inter- story drift, thereby protecting against possible harm caused by earthquakes.

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## To Study Municipal Solid Waste as Sustainable Energy Source for Conversion of MSW to Energy: Electricity

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**ABSTRACT**: Generating energy from waste is an evolving phenomenon now a day in most parts of the world. The establishment of Waste to Energy (WtE) generation plants using appropriate technologies is increasing both in developed and developing countries as one of the sustainable options for waste management. Most commonly used technologies for solid waste management worldwide, such as incineration, pyrolysis, gasification, anaerobic digestion, and land filling with gas recovery in order to achieve waste-to-energy.

The present study focuses on brief discussion on assessment of waste Quantification and Segregation, Physicochemical Properties and Energy Content of Municipal Solid Waste. To determine and assess the air pollutant emission levels from a Municipal Solid Waste (MSW) based Waste-to-Energy (WTE) plant using a Continuous Emission Monitoring System (CEMS). To assess the compliance of observed emission levels from the Waste-to-Energy (WTE) plant with the permissible limits specified by the Central Pollution Control Board (CPCB). This paper also addresses waste-to-energy (WtE) as a contributor to achieving sustainable development. Continuous Emission Monitoring Systems (CEMS) are devices used to measure and report real-time emission of air pollutants. Although CEMS have been extensively deployed in developed countries to ensure compliance with emission standards and enhance their environmental performance, their adoption in India is still in its early stages.

The seasonal emission analysis of the Waste-to-Energy (WTE) plant clearly demonstrates overall compliance with the Central Pollution Control Board (CPCB) standards across all monitored pollutants. All measured parameters including HCl, CO, SO<sub>2</sub>, CO<sub>2</sub>, H<sub>2</sub>O, O<sub>2</sub>, NO<sub>x</sub>, and particulate matter (PM) remained within permissible limits throughout the rainy, winter, and summer seasons. CO, CO<sub>2</sub>, O<sub>2</sub>, and PM emissions were consistently well within limits, reflecting effective combustion and pollution control mechanisms. The study highlights the WtE plant's role in sustainable waste management by converting 700 MT of segregated MSW daily into 14 MW of electricity without environmental impact. Across rainy, winter, and summer, all monitored pollutants remained within CPCB limits, ensuring safe operation of the waste to energy plant.

**KEYWORDS**: Municipal solid waste (MSW), Waste to energy(WTE), Central pollution control board (CPCB), Continuous Emission Monitoring Systems (CEMS)

#### I. INTRODUCTION

Waste-to-Energy (WtE) has played an important role in dealing with the increasing production of municipal solid waste (MSW). Stimulated by dwindling reserves of fossil fuels and sustainable energy production, WtE is seen as an attractive approach to recover energy and useful materials. (Jun Dong et al. (2019). Several investigations studied the quantifications and Segregation of the generated solid waste. Municipal solid wastes or urban solid wastes generally composed of a spectrum of refuse categories like food wastes, rubbish containing packing materials, demolition and construction wastes, street sweepings, garden wastes, abandoned parts of vehicles and appliances and residues from small scale industries. (Ragab Rabeiy et al. 2024). Physicochemical properties of waste, including temperature, calorific value, moisture content, and density, which are crucial for optimizing energy recovery processes. (A. Singhal, A.K. Gupta et al.2022).

Incineration is currently the most mature WtE technology with over 1400 plants in operation around the world. The emission of air pollutants from the municipal solid waste (MSW) incineration is one of the major concerns in air pollution. The emission factors (EFs) are the key parameters to estimate the emissions from MSW incineration. The MSW incineration could cause environmental and human health problems due to its emission of air pollutants, including acid gaseous pollutants of SO2, NOx, HCl, etc. (Xiaojia Chen et al.2022).



Continuous Emission Monitoring Systems (CEMS) are devices used to measure and report real-time emission of air pollutants. Although CEMS have been extensively deployed in developed countries to ensure compliance with emission standards and enhance their environmental performance, their adoption in India is still in its early stages. (Shrivastva et al. (2024).

Waste-to-Energy (WtE) is gaining global momentum as a sustainable alternative for municipal solid waste (MSW) management. Various studies have emphasized its potential to mitigate landfill dependency and generate renewable energy.

#### **II. OBJECTIVES OF THE STUDY**

The present study focusses on:

1.Assessment of Waste Quantification and Segregation at a Waste-to-Energy Plant

2. Characterization of the Physicochemical Properties and Energy Content of Municipal Solid Waste

3.To determine and assess the air pollutant emission levels from a Municipal Solid Waste (MSW) based Waste-to-Energy (WTE) plant using a Continuous Emission Monitoring System (CEMS).

4.To assess the compliance of observed emission levels from the Waste-to-Energy (WTE) plant with the permissible limits specified by the Central Pollution Control Board (CPCB).

This study presents a comprehensive assessment and performance analysis of the Waste-to-Energy (WtE) system from the PCMC study area. The research encompasses several critical components: quantification and source segregation of municipal solid waste (MSW) collected from the PCMC region, averaging approximately 1150 tonnes per day, with separation into dry and wet fractions. The MSW was characterized based on key physicochemical parameters including moisture content, density, temperature, and calorific value to evaluate its suitability for energy generation.

Air pollutant emissions specifically HCl, CO, SO<sub>2</sub>, NO<sub>x</sub>, CO<sub>2</sub>, and particulate matter (PM) were continuously monitored using a Continuous Emission Monitoring System (CEMS) across different seasonal conditions (winter, rainy, and summer). The observed emission levels were systematically compared with the permissible limits prescribed by the Central Pollution Control Board (CPCB) to assess regulatory compliance. Furthermore, the study evaluates the energy output of the WtE plant, rated at 14 MW, and examines its integration into the local infrastructure, including sewage treatment, water treatment plant, pumping station, and street lighting systems

#### III. METHODOLOGY







**1.Assessment of Waste Quantification and Segregation at a Waste-to-Energy Plant:** Approximately 700,000 kilograms (700 metric tonnes) of dry municipal solid waste (MSW) are collected daily from across the PCMC) region. The waste is initially segregated at the source into dry and wet fractions. The typical composition of the dry MSW is as follows: Food and garden waste: 40% (280,000 kg/day), Paper: 27% (189,000 kg/day), Inert materials (e.g., dust, debris): 15% (105,000 kg/day), Textile: 6% (42,000 kg/day), Plastic and rubber: 4% (28,000 kg/day), Glass and ceramic: 5% (35,000 kg/day), Metal: 3% (21,000 kg/day). The collected waste was quantified in terms of mass (kg/day) and further segregated into four categories biodegradable, non-biodegradable, recyclable, and inertusing a combination of manual sorting and mechanical separation techniques.

#### 2. Characterization of the Physicochemical Properties and Energy Content of Municipal Solid Waste

Characterization of MSW is the process of analysing its physical, chemical, and energy properties to assess its suitability for energy recovery. Physiochemical parameters of MSW were calculated or referenced to determine the suitability of the waste for energy generation:



Proceedings of International Conference on Innovation & Advancements in Civil Engineering (ICIAC-2025) 15<sup>h</sup> May 2025, Department of Civil Engineering, Ajeenkya D Y Paúll School of Engineering, Lohegaon, Pune, India, ISBN: 978-81-984557-3-4

**2.1Moisture Content (%)**: Determined using the formula:

Standard Procedure:

- 1. Take a representative sample of MSW (about 100–500 g).
- 2. Weigh the wet sample (W<sub>1</sub>).
- 3. Dry in a hot air oven at 105°C for 24 hours.
- 4. Weigh the dry sample (W<sub>2</sub>).
- 5. Moisture content (%) = Wet weight Dry weight/Wet weight x100

**2.2Density** (kg/m<sup>3</sup>):Its mass per unit volume (kg/m<sup>3</sup>), is a critical factor in the design of a SWM system, e.g., the design of sanitary landfills, storage, types of collection and transport vehicles, etc. A high in density of waste precludes the achievement of a high compaction ratio and the compaction n achieved is no greater. Density is the mass of MSW per unit volume.

Standard Procedure (Bulk Density): Take a container of known volume (V). Fill it with compacted MSW. Weigh the mass (M) of MSW inside. Formula: Density  $(kg/m^3) = M/V$ 

**2.3Calorific Value:** Calorific value of waste is defined as the amount of heat generated from combustion of a unit weight of the waste, expressed as kilojoule per kilogram (kJ/kg). Calorific value is the amount of heat energy released on combustion of 1 kg of MSW.

Standard Procedure:

- 1. Use a bomb calorimeter.
- 2. Take dried and ground MSW sample (~1g).
- 3. Burn in oxygen-rich environment in the calorimeter.
- 4. Measure the temperature rise of surrounding water.
- 5. Calculate CV (kcal/kg or MJ/kg) using calorimeter equations.

**2.4 Temperature:** Waste-to-energy plants, particularly those using incineration, rely on high temperatures to burn waste and generate heat for energy production, but these temperatures also pose challenges like corrosion and emissions. Temperature refers to the internal or surface temperature of MSW or a waste pile. Useful in composting or waste decomposition monitoring.

Standard Procedure:

- 1. Use a thermometer or temperature probe.
- 2. Insert it at various depths of the waste pile.
- 3. Record surface and internal temperatures.

# 3.To determine and assess the air pollutant (HCL, CO, SO2, CO<sub>2</sub>, H<sub>2</sub>0, 0<sub>2</sub>, NO<sub>x</sub>, P.M) emission levels from a Municipal Solid Waste (MSW) based Waste-to-Energy (WTE) plant using a Continuous Emission Monitoring System (CEMS).

A Continuous Emission Monitoring System (CEMS) is an integrated assembly of equipment designed to continuously collect, analyse, and record data on gas or particulate emissions from industrial processes. These systems are essential for ensuring compliance with environmental regulations by providing real-time monitoring of pollutants released into the atmosphere.

#### **3.1. CEMS Procedure:**

- 1. Sample Conditioning: The extracted gas is filtered and dried to remove particulates and moisture, ensuring accurate analysis.
- 2. Gas Analysis: Conditioned gas is analysed using sensors to measure concentrations of pollutants like SO<sub>2</sub>, NO<sub>x</sub>, CO, CO<sub>2</sub>, and O<sub>2</sub>.
- **3. Data Acquisition:** The Data Acquisition and Handling System (DAHS) collects and processes the analyzer data, converting it into standardized emission metrics.
- 4. Calibration: Regular calibration with known gas standards ensures measurement accuracy and system reliability. Reporting: Processed data is compiled into reports for regulatory compliance and environmental monitoring.



#### 3.2. Procedure for Zero Adjustment:

#### 1. Preparation:

- Ensure the analyser is operating under stable conditions and has reached its normal operating temperature.
- Verify that all components are functioning correctly and that there are no leaks or blockages in the system.

#### 2. Introduction of Zero Gas:

- Introduce a zero-calibration gas into the analyser. This gas is a mixture that contains no detectable amount of the target gas or any other gases that could interfere with the sensor.
- Common zero gases include purified air or nitrogen, depending on the application and the gases being monitored.
- 3. Adjustment:
- Allow the analyser to sample the zero gas for a sufficient period to ensure stabilization.
- Adjust the instrument's settings so that it reads zero in this environment, effectively setting the baseline for future measurements.

#### 3.3. Span Adjustment Procedure:

#### 1. Preparation:

- Warm-Up: Ensure the analyser has been powered on and has reached its stable operating temperature.
- Equipment Check: Verify that all components, including sample lines and filters, are in good condition and free from contaminants.

#### 2. Selection of Span Gas:

Concentration: Choose a certified span gas with a known concentration, typically around 80% of the analyser's full-scale measurement range. This concentration is selected to provide a robust calibration point within the instrument's operating range.

### 4.To assess the compliance of observed emission levels from the Waste-to-Energy (WTE) plant with the permissible limits specified by the Central Pollution Control Board (CPCB):

Emission Standards for Waste-to-Energy (WTE) plants as per the Solid Waste Management (SWM) Rules, 2016 and Central Pollution Control Board (CPCB) guidelines. These limits are meant to control air pollution from waste-to-energy plants. The units used are mg/Nm<sup>3</sup> (milligrams per normal cubic meter)

#### **Table:1 Emission Standards for WTE Plants**

	Emission Standards for Waste-to-Energy (WTE) plants					
Parameter	as per the Solid Waste Management (SWM) Rules, 2016 and					
	Central Pollution Control Board (CPCB)					
HCL (mg/Nm3)	50					
CO (mg/Nm3)	100					
SO2 (mg/Nm3)	200					
CO2 (mg/Nm3)	100					
H2O (%)	25					
O2 (%)	25					
NOX (mg/Nm3)	400					
DUST PM (mg/Nm3)	50					

#### **IV. EXPERIMENTAL RESULT**

To evaluate the environmental performance of the Waste-to-Energy (WtE) plant, emissions of key pollutants were monitored across three seasons Rainy (July), Winter (November), and Summer (February) and compared with Emission Standards for Waste-to-Energy (WTE) plants as per the Solid Waste Management (SWM) Rules, 2016 and Central Pollution Control Board (CPCB)

#### 1.Assessment of Waste Quantification and Segregation at a Waste-to-Energy Plant

Approximately 700,000 kilograms (700 metric tonnes) of dry municipal solid waste (MSW) are collected daily from across the PCMC region. The waste is initially segregated at the source into dry and wet fractions. The typical composition of the dry MSW is as follows: Food and garden waste: 40% (280,000 kg/day), Paper: 27% (189,000 kg/day), Inert materials (e.g., dust, debris): 15% (105,000 kg/day), Textile: 6% (42,000 kg/day), Plastic and rubber: 4% (28,000 kg/day), Glass and ceramic: 5% (35,000 kg/day), Metal: 3% (21,000 kg/day). The collected waste was quantified in terms of mass (kg/day) and further segregated into four categories biodegradable, non-biodegradable, recyclable, and inert using a combination of manual sorting and mechanical separation techniques.



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Category	Percentage (%)	Weight (kg/day)		
Food & Garden Waste	40%	280000		
Paper	27%	189000		
Inert	15%	105000		
Textile	6%	42000		
Plastic/Rubber	4%	28000		
Glass & Ceramic	5%	35000		
Metal	3	21000		

#### Table:2: Quantification and Segregation Municipal Solid Waste



### Figure 2:Quantification and Segregation of waste

#### 2. Characterization of the Physicochemical Properties and Energy Content of Municipal Solid Waste

Characterization of MSW is the process of analysing its physical, chemical, and energy properties to assess its suitability for energy recovery. The waste was analysed for key properties affecting energy recovery. Moisture content was highest in the rainy season and lowest in winter. Density ranged from 250–350 kg/m<sup>3</sup>. The calorific value varied seasonally about 1400–1700 kcal/kg in the rainy season, 1800–2500 kcal/kg in winter, and 1600–2200 kcal/kg in summer indicating its suitability for energy generation.

#### Table 3: Physicochemical Properties and Energy Content of Municipal Solid Waste for WTE Application

Danamatan	<b>U</b>	Standard value	Test value		
Parameter	Unit	Standard value	No:1	No:2	
Moisture content	%	40-60%	47.15	22.83	
Density	gm/cm3	0.30-0.50	0.42	0.18	
Calorific value	Kcal/kg	1500-2500	1570	1850	
Temperature	Degree	0-150	70.10	23.61	

### 4.To assess the compliance of observed emission levels from the Waste-to-Energy (WTE) plant with the permissible limits specified by the Central Pollution Control Board (CPCB):

### Table 4:Seasonal Variation of Emission Parameters from Waste-to-Energy (WTE) Plant Compared with CPCB Permissible Limits

Parameter	Emission	Rainy Season			Winter Season			Summer Season		
1	Standards	(JULY)			(NOVEMBER)			(FEBRUARY)		
HCL (mg/Nm <sup>3</sup> )	50	2.11	36.51	48.16	18.22	47.60	40.98	23.72	49.98	30.97
CO (mg/Nm <sup>3</sup> )	100	8.72	42.19	0.00	0.02	0.02	12.65	0.01	0.03	0.17
SO2 (mg/Nm <sup>3</sup> )	200	52.16	158.57	104.37	61.77	61.77	173.70	84.48	123.60	109.13
CO2 (mg/Nm <sup>3</sup> )	100	0	12.75	10.67	10.51	10.51	13.02	12.01	11.34	12.86
H2O (%)	25	1.27	24.99	21.17	20.70	20.72	24.99	22.68	22.37	23.41
O2 (%)	25	22.78	5.95	7.44	8.34	8.14	4.68	7.38	5.68	6.11
$NO_X(mg/Nm^3)$	400	16.44	208.30	388.43	330.06	330.06	204.31	304	304	302.41
DUST PM	50	0.04	1.36	1.37	1.37	1.37	18.90	18.90	16.90	23.26
(mg/Nm3)										



#### Table 5:Compliance of observed emission levels from the Waste-to-Energy (WTE) plant

	Parameter	Result and Discussion
1	HCL (mg/Nm <sup>3</sup> )	HCl concentrations across all three seasons remained below the CPCB threshold of 50 mg/Nm <sup>3</sup> . The maximum recorded values were 48.16 mg/Nm <sup>3</sup> in the rainy season, 47.60 mg/Nm <sup>3</sup> in winter, and 49.98 mg/Nm <sup>3</sup> in summer. Although values approached the regulatory limit during summer and rainy periods, no exceedance was observed. This indicates effective functioning of plant
2	CO (mg/Nm <sup>3</sup> )	The CO emission values were consistently well within CPCB permissible limits across all seasons. Peak concentrations were 42.19 mg/Nm <sup>3</sup> (rainy) due to excess moisture content. This suggests stable and efficient combustion conditions, Lower values in summer reflect higher thermal efficiency, likely due to drier feedstock and optimal combustion temperatures.
3	SO <sub>2</sub> (mg/Nm <sup>3</sup> )	SO <sub>2</sub> concentrations remained below the regulatory threshold in all seasons. Maximum values were 158.57 mg/Nm <sup>3</sup> (rainy), 173.70 mg/Nm <sup>3</sup> (winter), and 123.60 mg/Nm <sup>3</sup> (summer). Although the highest values were recorded in the winter season, likely due to higher sulphur content in the feedstock and decreased atmospheric dispersion, the emissions remained compliant.
4	CO <sub>2</sub> (mg/Nm <sup>3</sup> )	CO <sub>2</sub> levels were significantly lower than the CPCB limit across all seasons, with maximum concentrations of 12.75 mg/Nm <sup>3</sup> (rainy), 13.02 mg/Nm <sup>3</sup> (winter), and 12.86 mg/Nm <sup>3</sup> (summer).
5	H <sub>2</sub> O (%)	Moisture content in the flue gas stream, as measured by water vapour percentage, was within the prescribed 25% limit for all seasons. Maximum recorded values were 24.99% (rainy and winter) and 23.41% (summer). Seasonal variation follows expected trends, with higher moisture content during the rainy and winter periods due to increased humidity and wet waste input.
6	O <sub>2</sub> (%)	Oxygen levels in the flue gas were well within the CPCB limit throughout the year. Peak values reached 22.78% (rainy), 8.34% (winter), and 7.38% (summer). Higher oxygen levels in the rainy season suggest excess air supply to compensate for high-moisture waste
7	NO <sub>X</sub> ( mg/Nm <sup>3</sup> )	NO <sub>x</sub> emissions were consistently below but close to the CPCB threshold in all three seasons, with recorded maximum value of 388.43 mg/Nm <sup>3</sup> (rainy) Although no regulatory violations occurred.
8	DUST PM (mg/Nm3)	Particulate emissions were well within the CPCB-prescribed limit across all seasons. Peak concentrations were 1.37 mg/Nm <sup>3</sup> (rainy and winter) and 23.26 mg/Nm <sup>3</sup> (summer). The observed rise in summer may be attributed to dry weather, increased fly ash entrainment

#### **V. CONCLUSION**

The seasonal emission analysis of the Waste-to-Energy (WTE) plant clearly demonstrates overall compliance with the Central Pollution Control Board (CPCB) standards across all monitored pollutants. All measured parameters including HCl, CO, SO<sub>2</sub>, CO<sub>2</sub>, H<sub>2</sub>O, O<sub>2</sub>, NO<sub>x</sub>, and particulate matter (PM) remained within permissible limits throughout the rainy, winter, and summer seasons.CO, CO<sub>2</sub>, O<sub>2</sub>, and PM emissions were consistently well within limits, reflecting effective combustion and pollution control mechanisms. The moisture content and oxygen levels also exhibited expected seasonal variations, influenced by waste feedstock characteristics and humidity. Overall, the WTE plant demonstrates sound operational performance and environmental sustainable.

Despite seasonal variations in waste composition and calorific value lowest during the rainy season and highest in winter the plant consistently demonstrated efficient combustion, with low CO and particulate matter levels indicating effective pollution control systems. The study highlights the WtE plant's role in sustainable waste management by converting 700 MT of segregated MSW daily into 14 MW of electricity without environmental impact. Across rainy, winter, and summer, all monitored pollutants remained within CPCB limits, ensuring safe operation of the waste to energy plant.



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